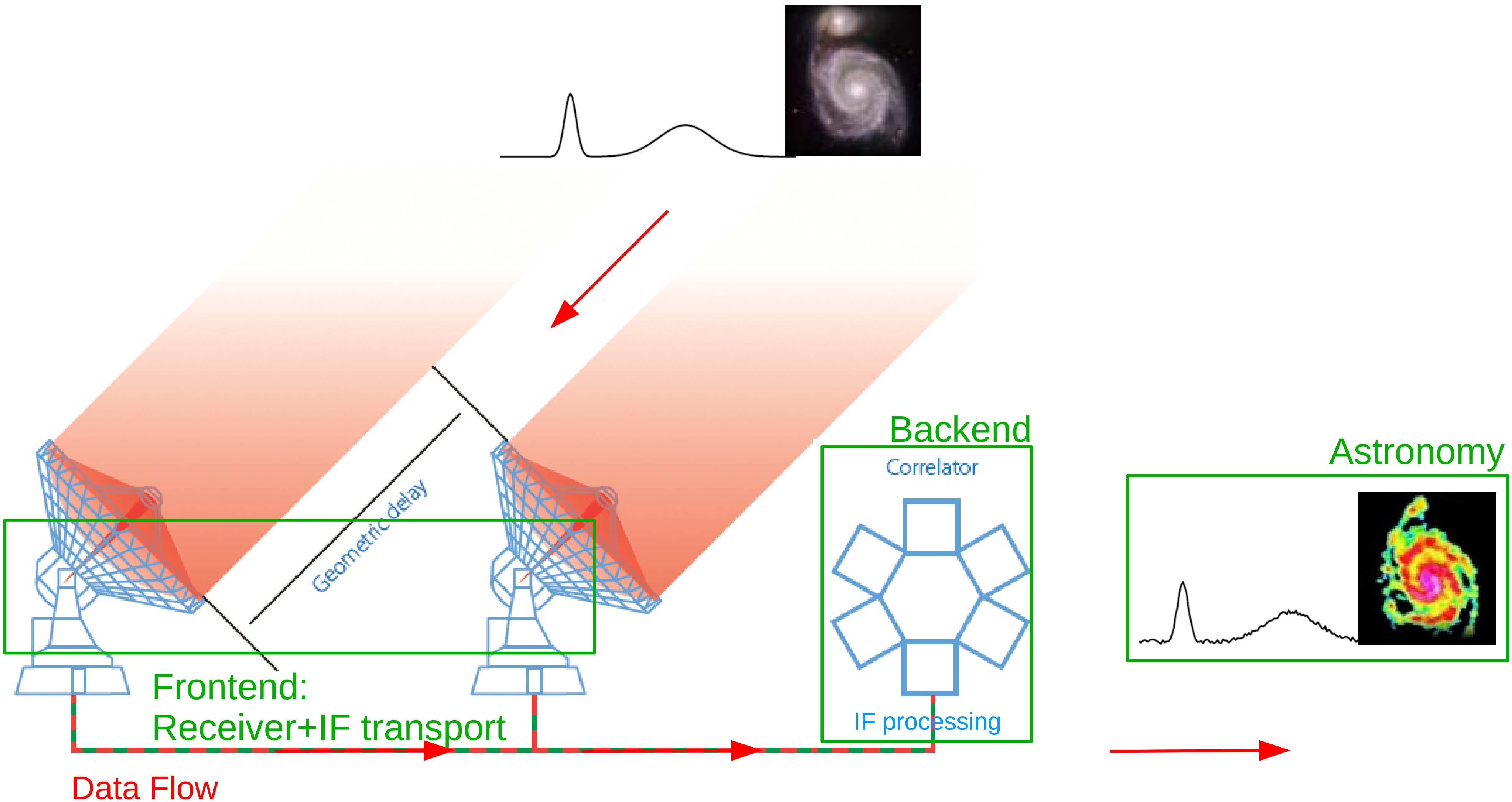
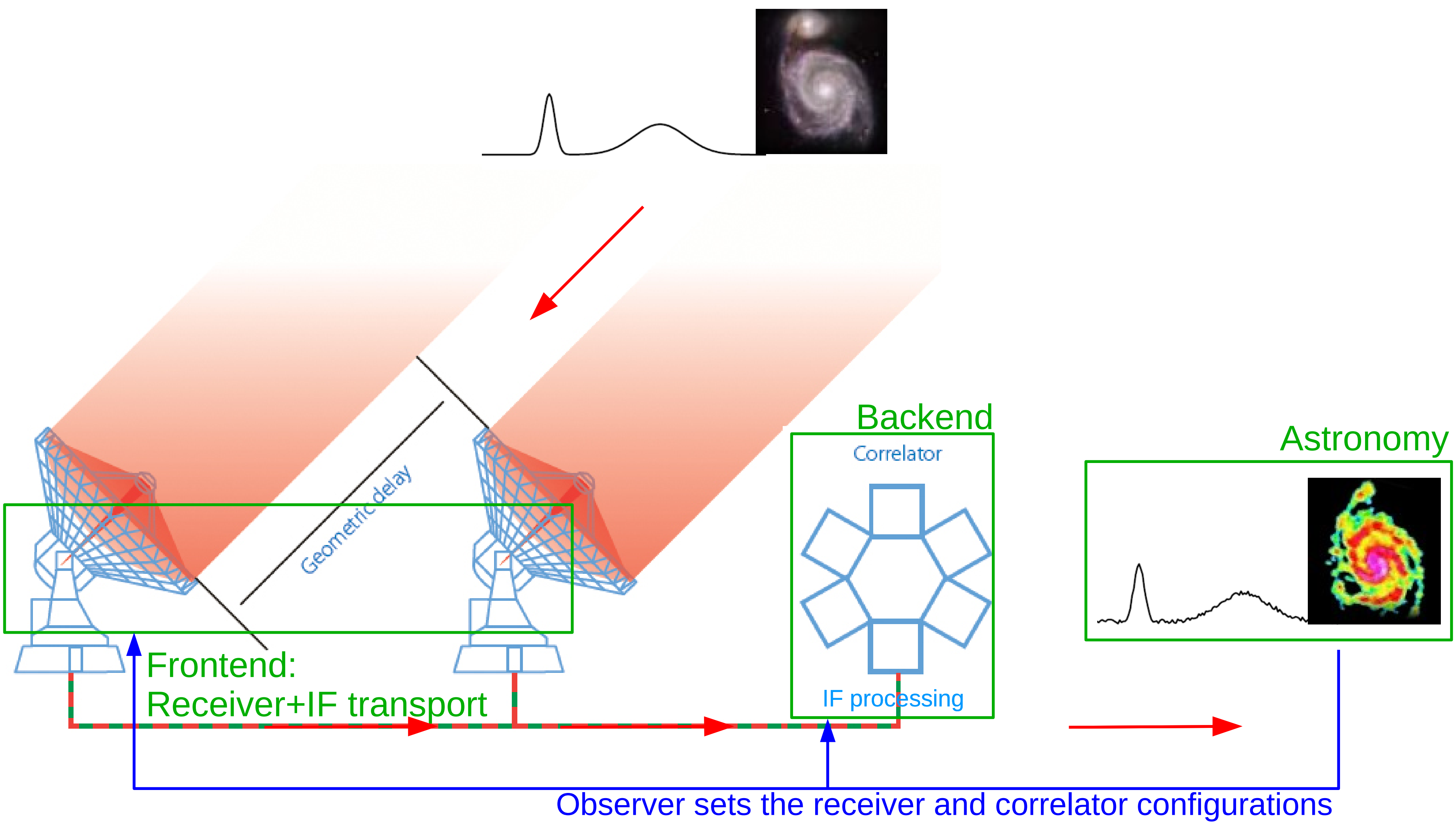
NOEMA spectral setups
Nomenclature and ASTRO implementation
29-Jul-2022

Jeremie Boissier

Overview


Geometric delay
Backend
Correlator
IF processing
Astronomy
Frontend:
Receiver+IF transport
Data Flow

Overview


Geometric delay
Backend
Correlator
IF processing
Astronomy
Frontend:
Receiver+IF transport
Observer sets the receiver and correlator configurations

Outline

1. NOEMA frontend and associated nomenclature

- Receiver Bands
- IF Outputs

2. NOEMA backend and associated nomenclature

- IF Processing (Basebands)
- Correlator modes
- Spectral windows

3. Preparing observations in GILDAS\ASTRO

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NOEMA Frontend

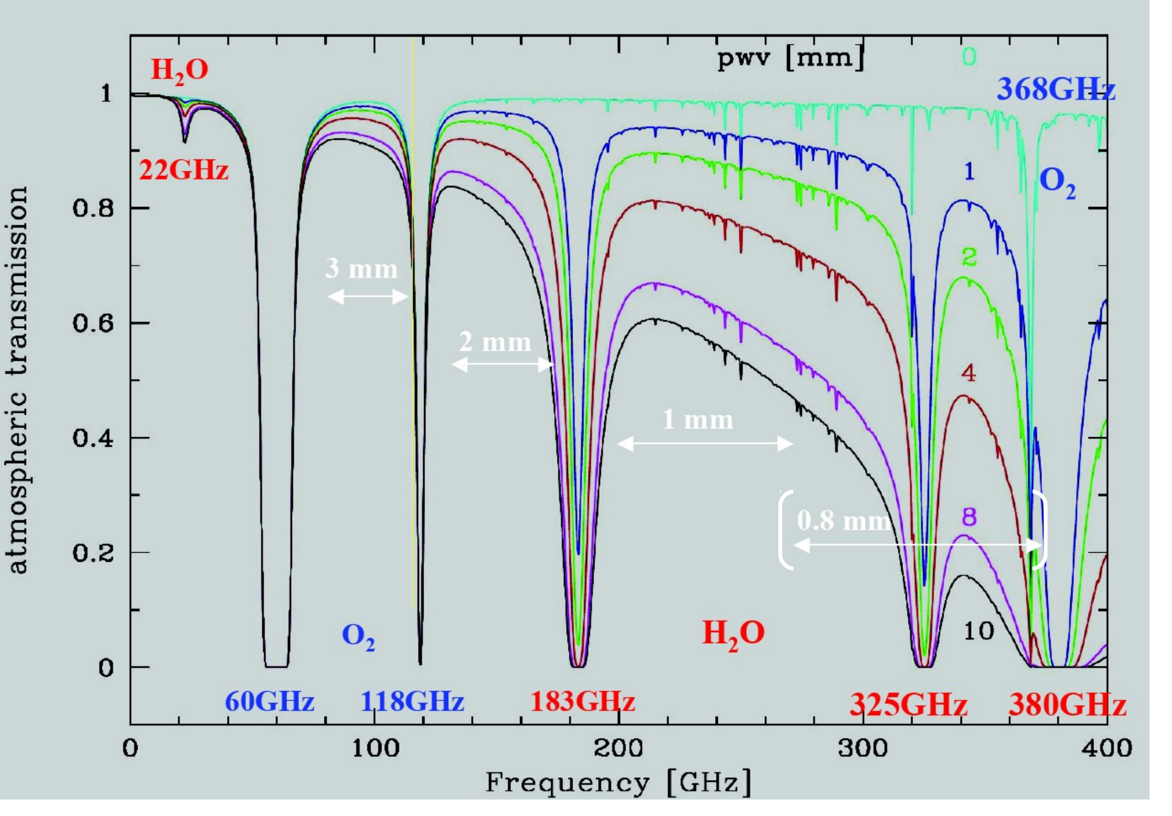
NOEMA antennas are equipped with heterodyne receivers

- Input: Radio frequency signal at ~mm wavelengths (~70-380GHz)
- Output: Slices of sky signal down converted to lower frequencies (~0-20GHz)

  Size of the slices = **IF Bandwidth** (~8 GHz in case of NOEMA)

- Detecting devices are sensitive to narrow (~50-100 GHz) ranges of the spectrum
  - 4 **receiver bands** to cover 70 – 380 GHz range (i.e. 0.8 to 4.3 mm)
  - Call S17: Band 4 not available

	F_{min} GHz	F_{max} GHz
Band 1 (3mm)	70.384	119.872
Band 2 (2mm)	127.000	182.872
Band 3 (1mm)	196.128	276.000



NOEMA Frontend

Heterodyne systems

- Down-convert the spectrum

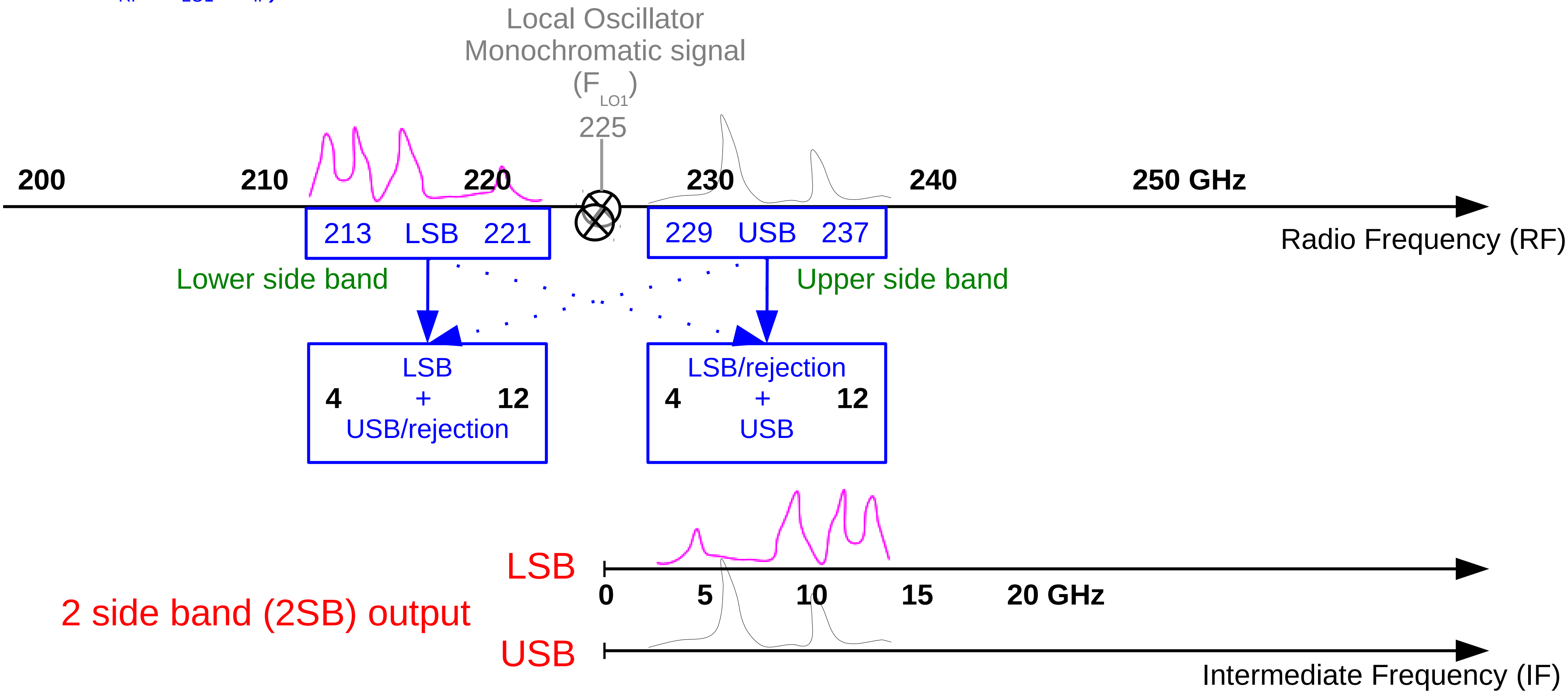
  from Radio Frequency (740< F_{RF}< 280 GHz in case of NOEMA)

  to Intermediate Frequency (4 < F_{IF} < 12 GHz)

  Done by mixing sky signal with locally produced reference frequency (Local Oscillator Frequency)

  Tuning the receiver = setting the reference F_{LO1} + optimizing some hardware parameters

- 2SB receiver band delivers **2 IF outputs** of ~8 GHz width (LSB: $F_{RF}=F_{LO1}-F_{IF}$ and USB: $F_{RF}=F_{LO1}+F_{IF}$)



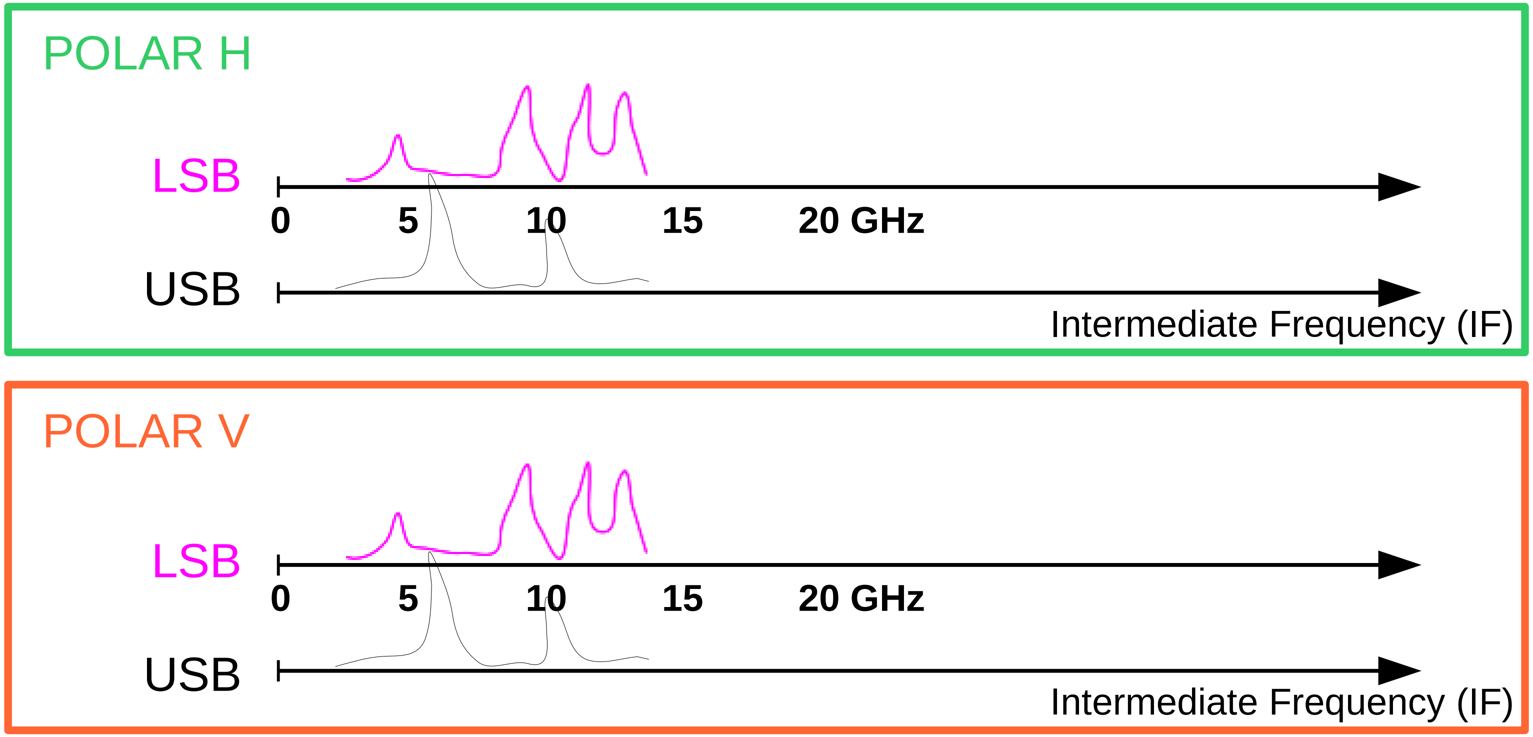
NOEMA Frontend

Dual polarization

- 1 NOEMA receiving system detects 1 linear polarization
- Each receiver band contains 2 receiving systems: Horizontal and Vertical polarization
  - Separation grid on the incident path
  - Each receiver band contains 2 mixer-blocks (H,V) made of 2 mixers (USB,LSB)
  - H and V are independent: gain factor of 2 on time
  - No polarimetry yet (no cross product)
- Dual polar, 2SB receiver band delivers **4 IF outputs**:

  HLSB HUSB VLSB VUSB

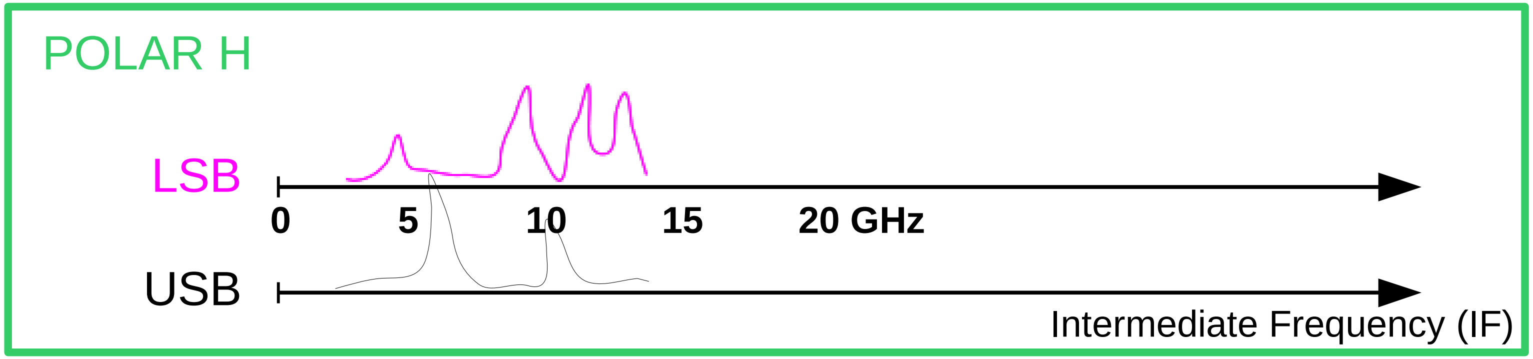
  They are all brought to the correlator room through optic fibers

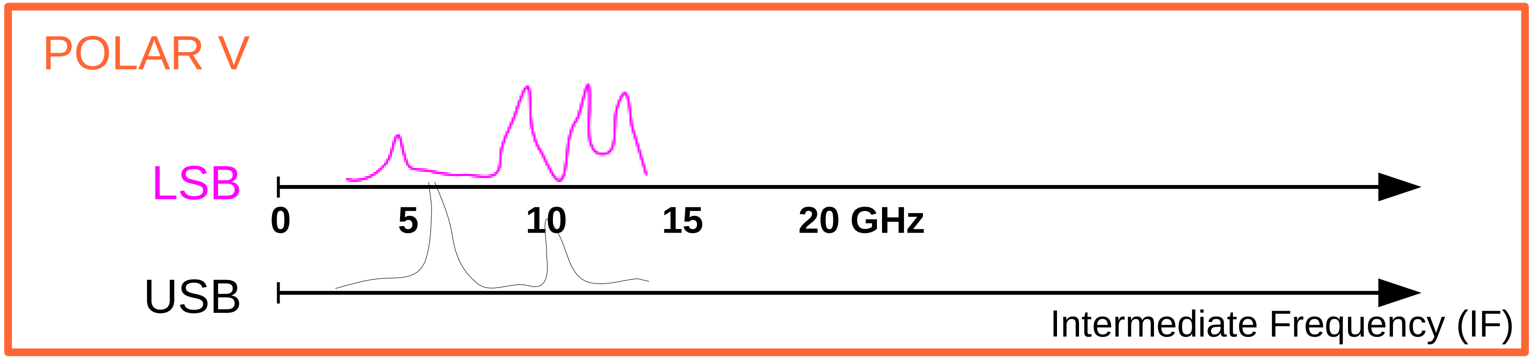


NOEMA Frontend

Summary and nomenclature

- NOEMA antennas are equipped with 2SB, dual polarization, heterodyne receivers
  - Band 1: 70.4-121.6 GHz
  - Band 2: 124.4-183.6 GHz
  - Band 3: 196.4-279.6 GHz
- Tuning a receiver band = setting $F_{LO1} = F_{RF} +/- F_{IF}$
- NOEMA Receiver delivers 4 IF outputs:
  - HLSB HUSB VLSB VUSB
  - Width= ~8GHz
  - From ~4 to ~12 GHz in IF





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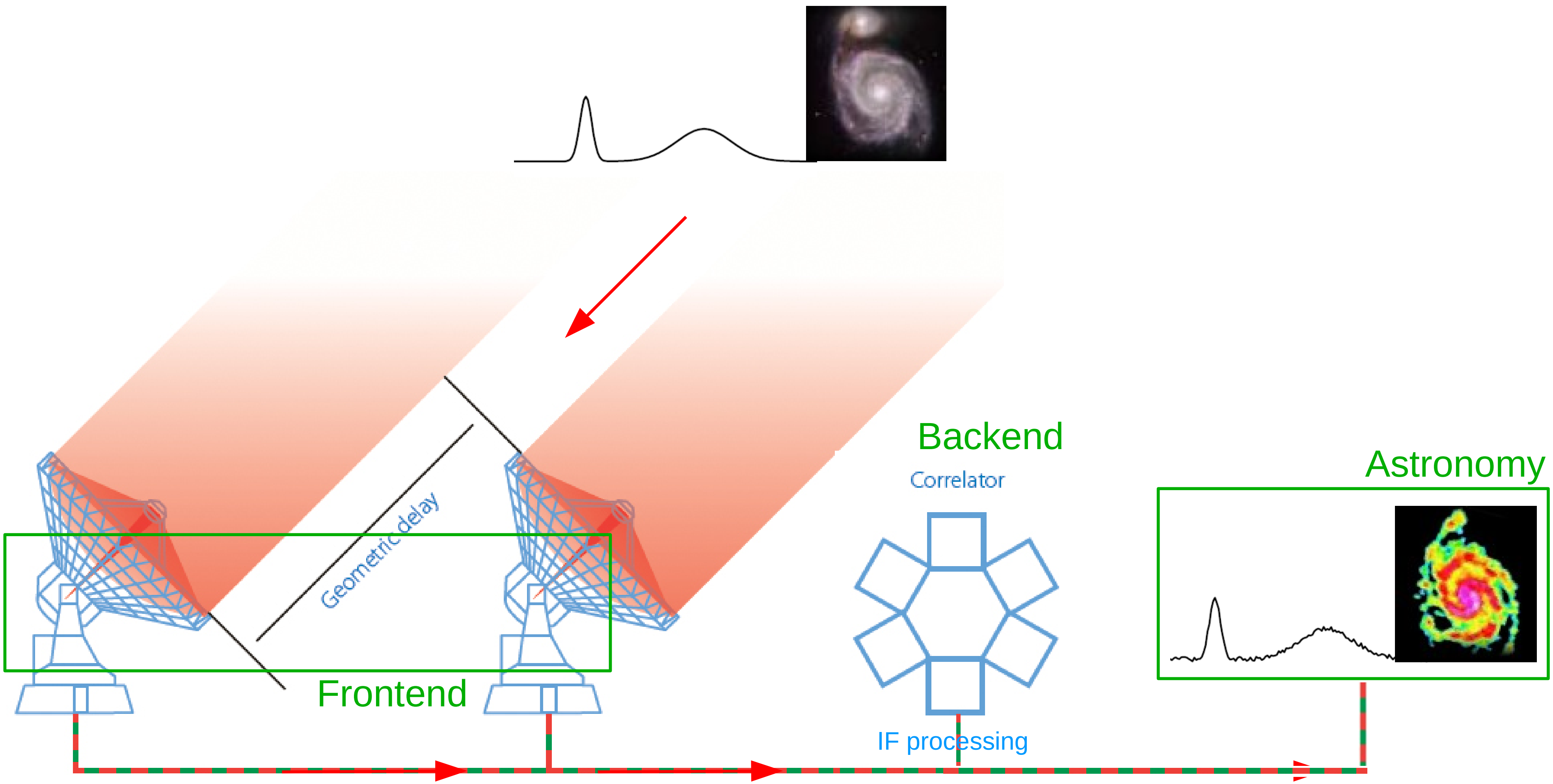
Geometric delay
Frontend
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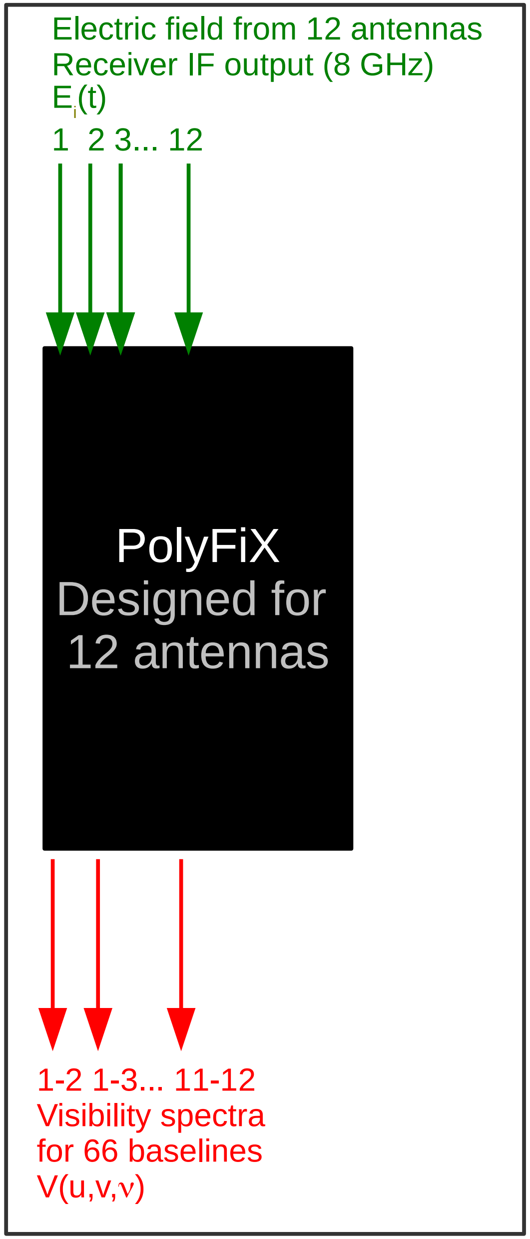
NOEMA Backend

Very simplified view of a correlator



x 4 (H-USB,H-LSB,V-USB,V-LSB)

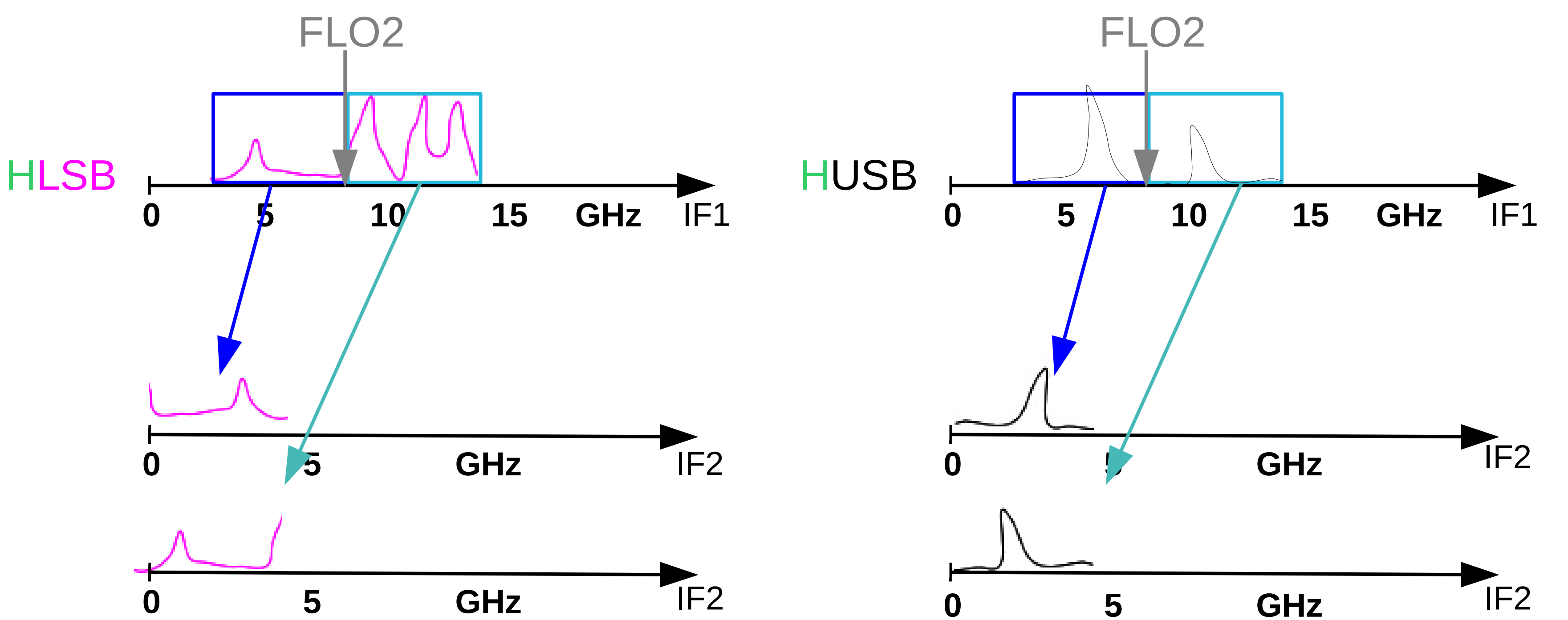
For each IF output from receivers:

- Analog to Digital conversion
  - Correlator receives analogical signal from all the antennas
  - The wider the band, the more difficult the conversion
    - Choice to split the input bandwidth into 2 parts of 4GHz
      0-4 GHz Basebands
      Done in the IF Processor
- Correlation

NOEMA Backend

IF Processing

- Adapt the output of the receiver to the input of the correlator
  - 1 NOEMA receiver band delivers 4 x ~8 GHz sidebands [4-12 GHz IF1]
  - 1 NOEMA correlator unit accepts 1 x ~4 GHz [0-4 GHz IF2] x 12 antennas
- IF processor splits each sideband into 2 x ~4GHz **basebands**
  - Downconvertion to 0-4 GHz IF2



NOEMA Backend

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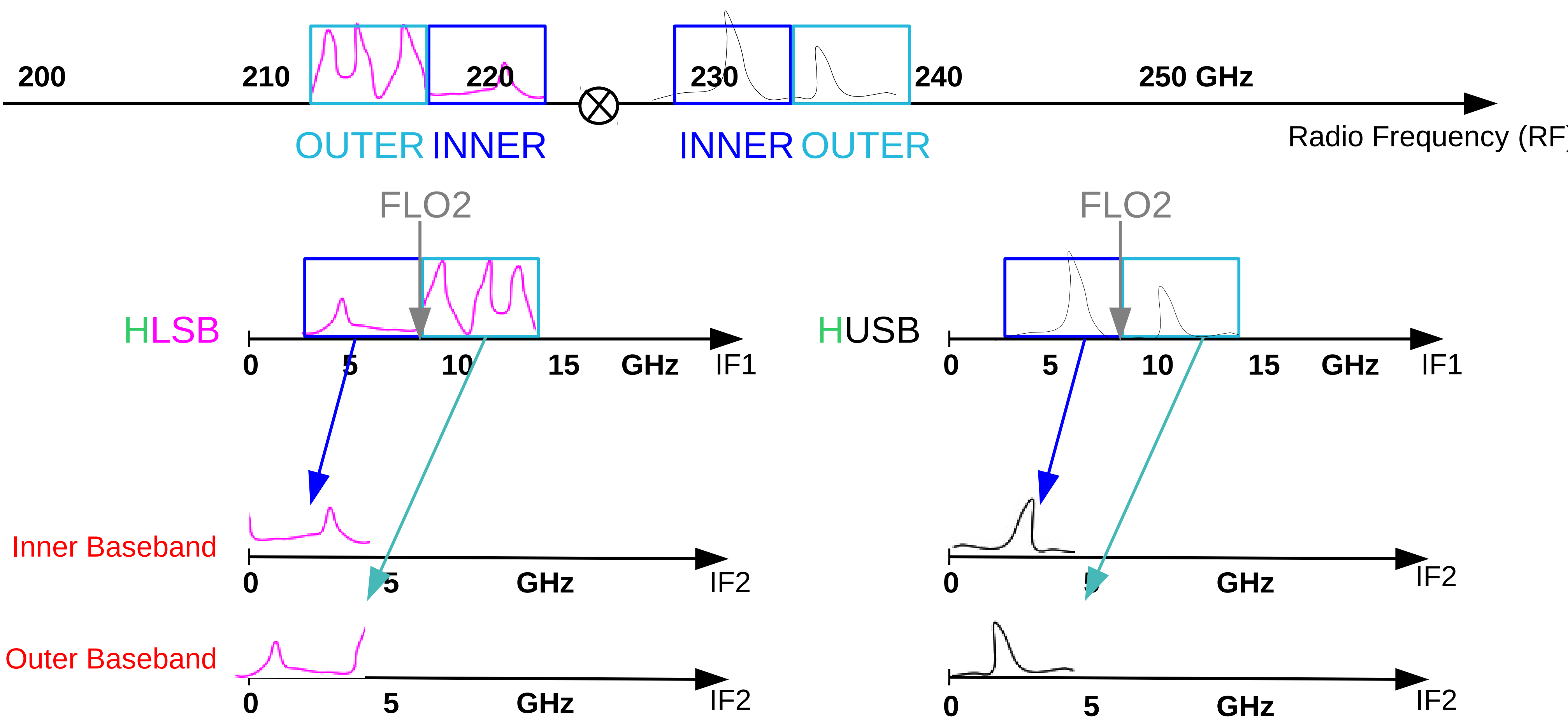
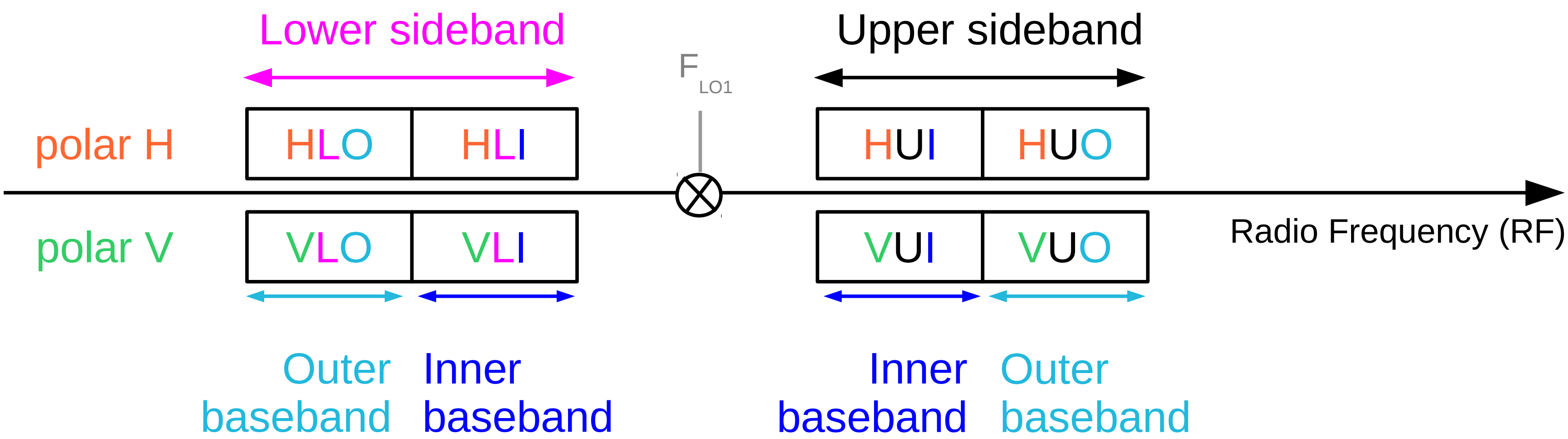
  - 1 NOEMA receiver band delivers 4 x ~8 GHz sidebands [4-12 GHz IF1]
  - 1 NOEMA correlator unit accepts 1 x ~4 GHz [0-4 GHz IF2] x 12 antennas
- IF processor splits each sideband into 2 x ~4GHz **basebands**
  - Nomenclature: Outer and Inner baseband



NOEMA Backend

IF processing summary:

8 Basebands (0-4 GHz IF2) feed 8 correlator units



NOEMA Backend

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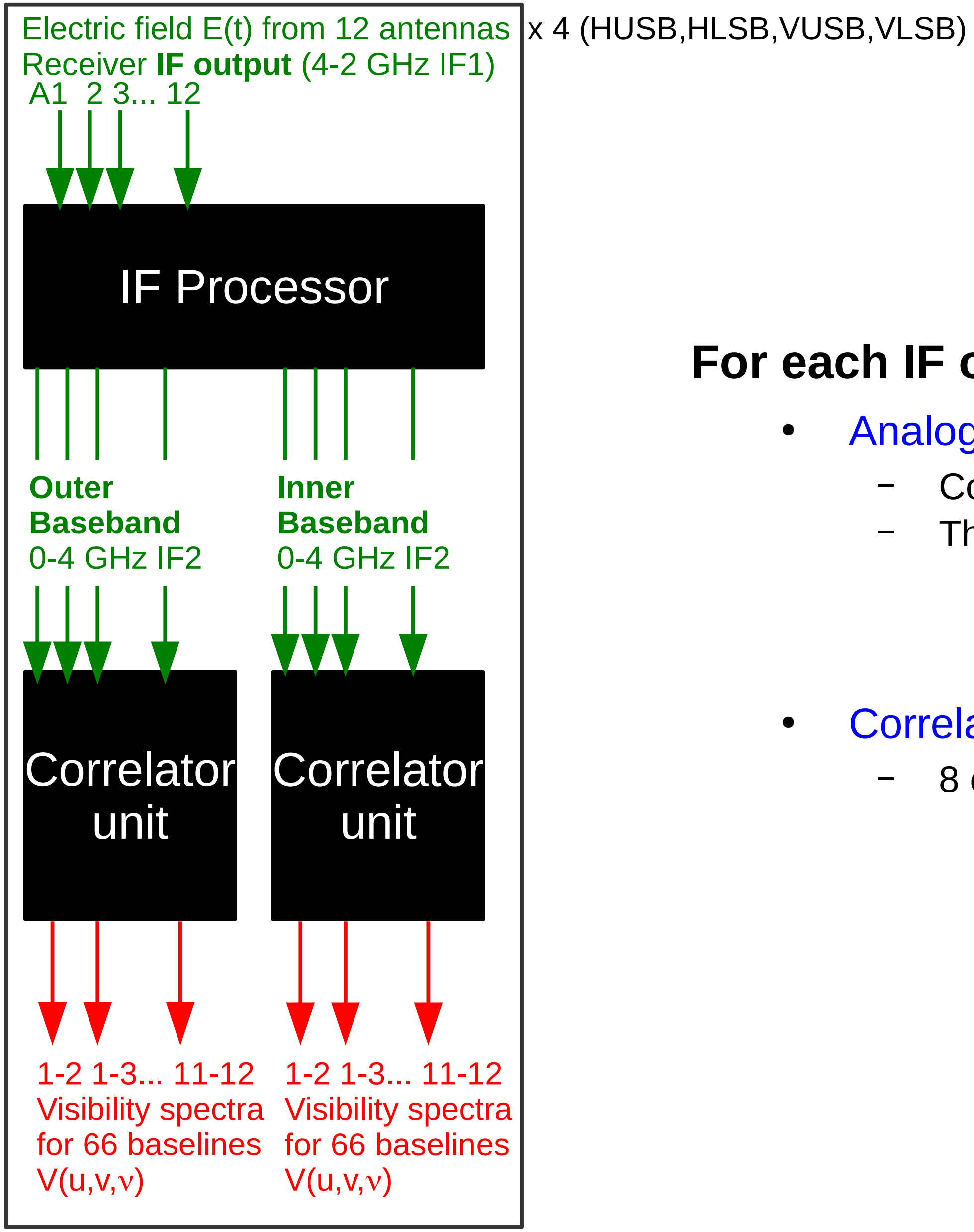


For each IF output from receivers:

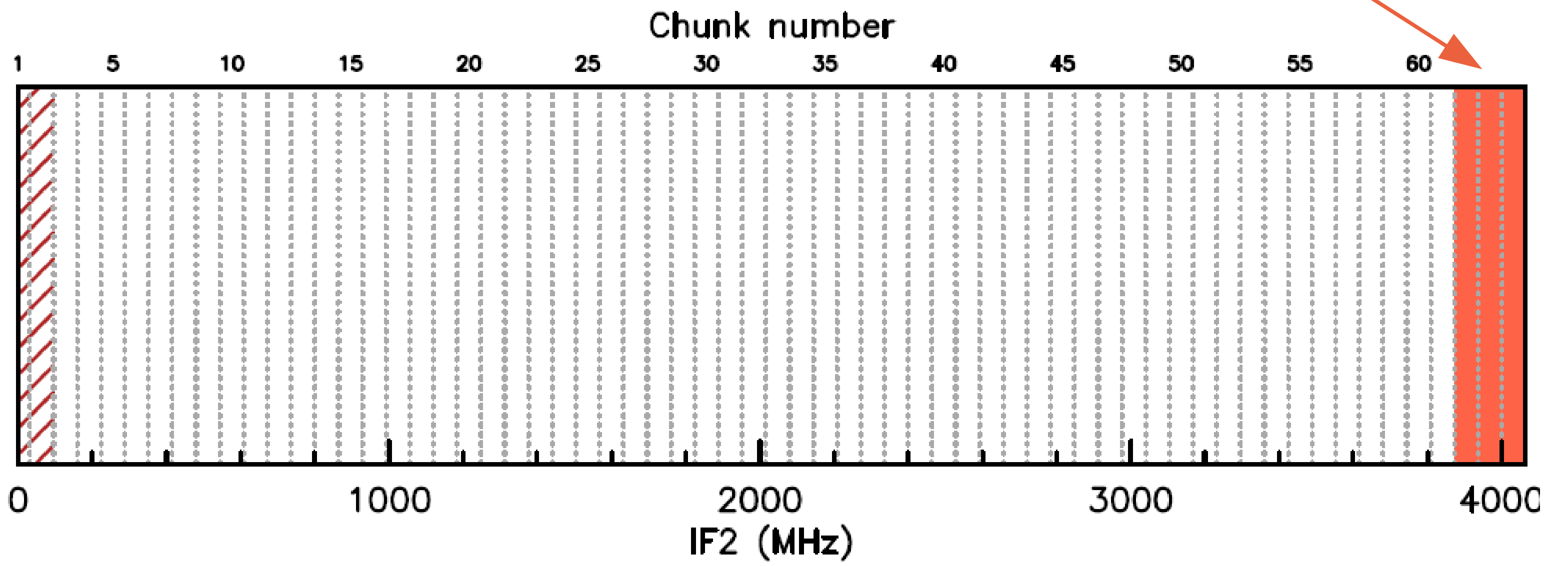
- Analog to Digital conversion
  - Correlator receives analogical signal from all the antennas
  - The wider the band, the more difficult the conversion
    - Choice to split the input bandwidth into 2 parts of 4GHz
      0-4 GHz Basebands
      Done in the IF Processor
- Correlation of 2 independent basebands
  - 8 correlator units in total

NOEMA Backend

PolyFiX correlator: 8 identical and independent units

- Input: 0-4 GHz baseband (x 12 antennas)
- Signal is digitized
- Baseband is split in **64 Chunks** of 64 MHz on a fixed grid
  - “Overlapping Polyphase Filter Bank”
  - Last 3 chunks thrown away (antialiasing filter)

    Effective bandwidth=3872 MHz

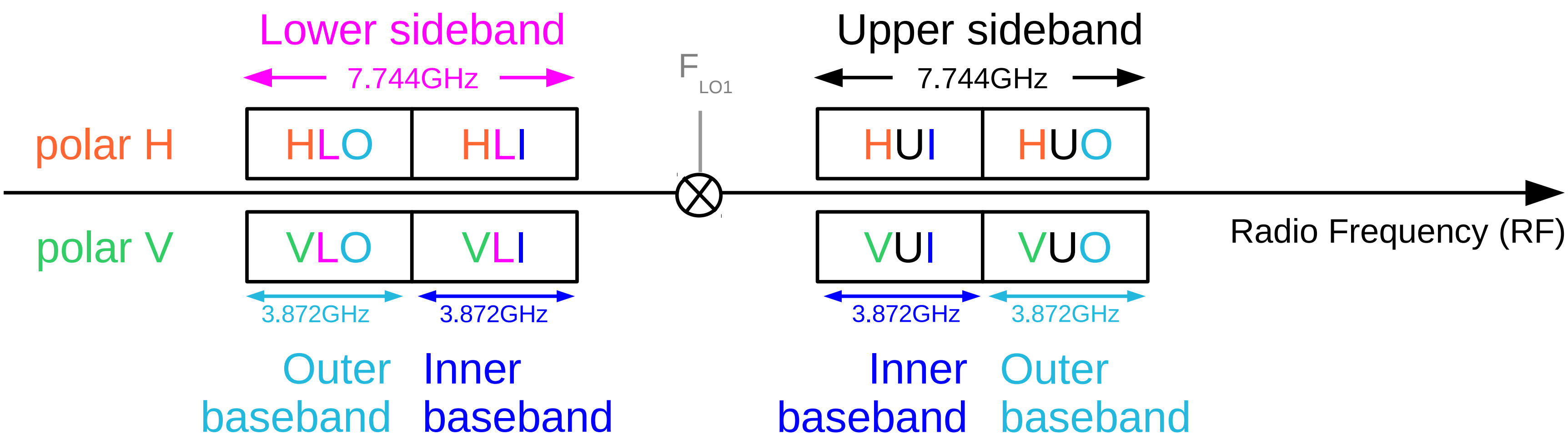


NOEMA Backend

Summary:

8 Basebands (0-4 GHz IF2) feed 8 correlator units

- With exact bandwidth:



NOEMA Backend

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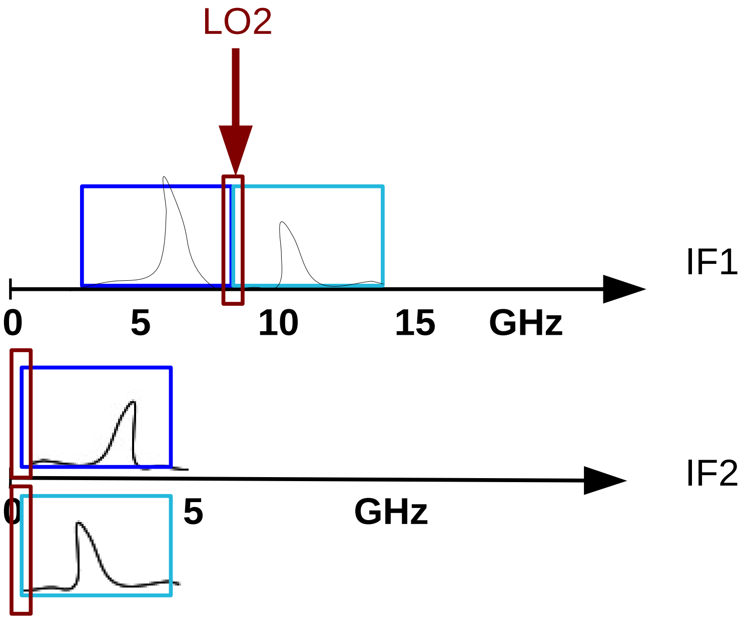
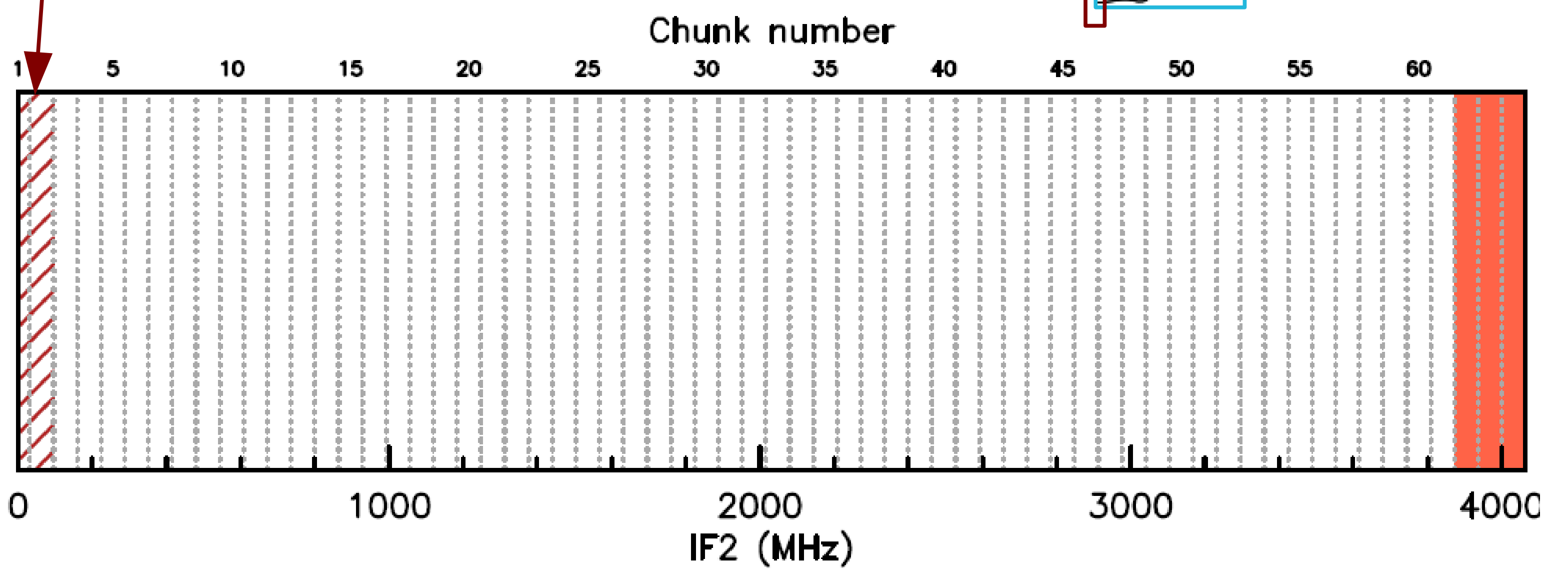
- Signal is digitized
- Baseband is split in **64 Chunks** of 64 MHz on a fixed grid
  - "Overlapping Polyphase Filter Bank"
  - Last 3 chunks thrown away (antialiasing filter)
    Effective bandwidth=3872 MHz
  - LO2 Separation:
    - Parasite at 0 MHz IF2 (7744 IF1)
      - First 10 MHz unusable
    - Efficiency loss in the first 50 MHz





NOEMA Backend

PolyFiX correlator: 8 identical and independent units

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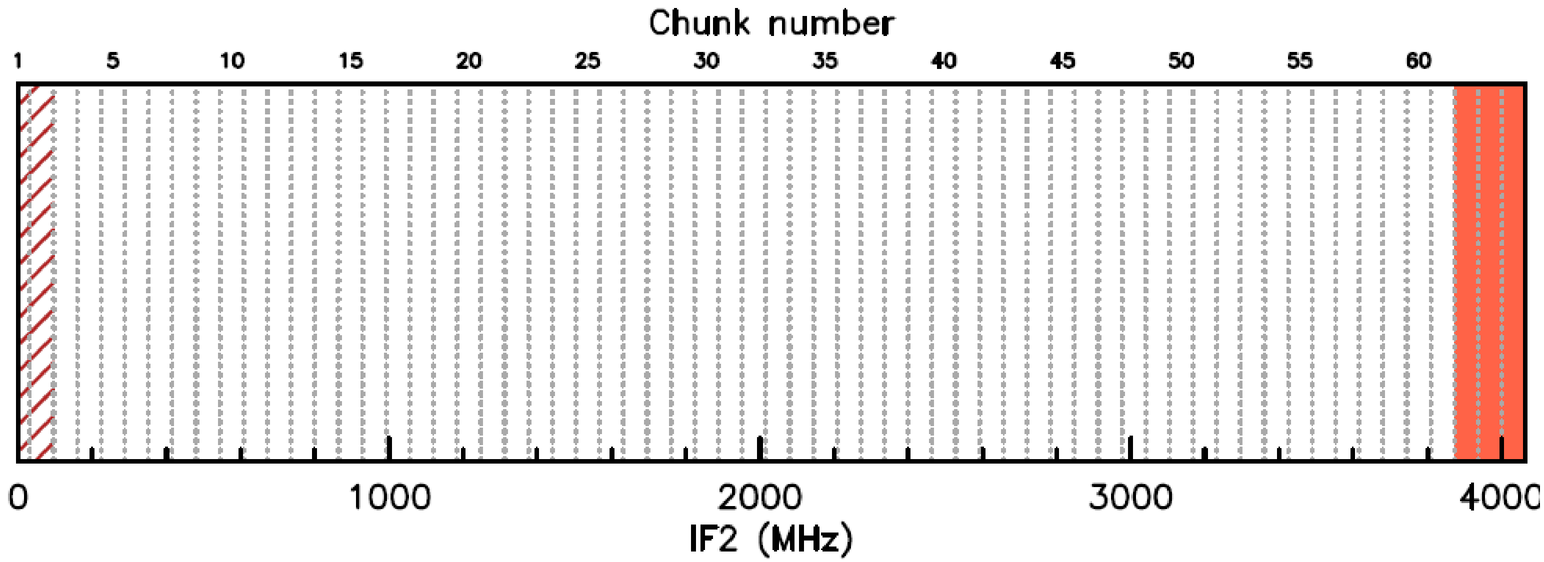
- Signal is digitized
- Baseband is split in **64 Chunks** of 64 MHz on a fixed grid
  - "Overlapping Polyphase Filter Bank"
  - Last 3 chunks thrown away (antialiasing filter)
    Effective bandwidth=3872 MHz
  - LO2 Separation:
    - First 10 MHz unusable
    - Efficiency loss in the first 100 MHz
- Fourier Transform and cross multiplication (FX)
  - Done chunk by chunk
  - Reprogrammable: **Correlator modes**



NOEMA Backend

PolyFiX correlator Modes:

- Capabilities for a single unit
- **Original Mode**: Continuum + Lines
  - 61 chunks at Low resolution (2MHz); total bandwidth 3872 MHz

  AND 16 chunks at High resolution (62.5kHz); bandwidth 64 MHz each
  - Unique mode at delivery in 2017
- **Mode available as of 2022**: 250kHz
  - 61 chunks at 250 kHz; total bandwidth 3872 MHz
- **Future mode** : Continuum and high resolution lines [not available yet]
  - Similar to mode 1 with higher resolution in less chunks

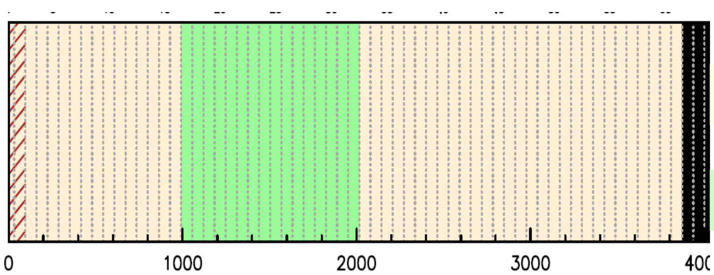
	1 Unit	All Units
Default Mode: Continuum + Lines	61 chunks (3872 MHz) at 2 MHz resolution **AND** 16 chunks at 62.5 kHz resolution*	~16 GHz x 2 polar with 2 MHz channels **AND** 8 GHz with 62.5kHz channels*
Mode 250kHz	61 chunks (3872 MHz) at 250 kHz resolution	~16 GHz x 2 polar with 250 kHz channels
Mode 3: Continuum + High Resolution	<61 chunks (3872 MHz) at 2 MHz resolution AND 8/4/2 chunks at 31.25/15.625/7.8125 kHz resolution*	<16 GHz x 2 Polar with 2 MHz channels AND 4/2/1 GHz with 31.25/15.625/7.8125kHz channels*

*High resolution chunks chosen among the 61 of the **fixed** filter bank

NOEMA Backend

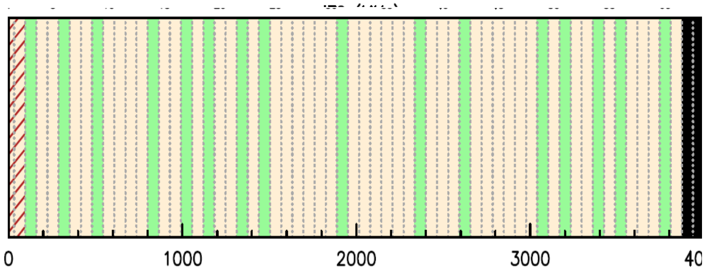
Nomenclature: Spectral windows

- The output of the correlator is a number of **spectral windows**
- In a given baseband, a **spectral window** is
  a set of contiguous chunks processed at the same spectral resolution
- With the default mode:
  - 1 Correlator Unit output is made of:
    - 1 low resolution spectral window (made of 61 chunks)
    - $1<n_{spw}<16$ high resolution spectral windows (made of $16>n_{chunks}>1$ chunks)



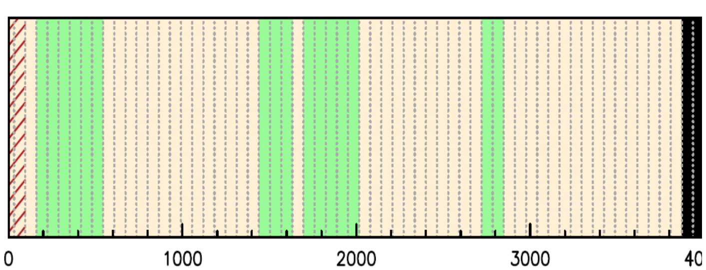
1 low resolution SPW (3872 MHz wide, 2000 kHz channels)

1 high resolution SPW (1024 MHz wide, 62.5 kHz channels)



1 low resolution SPW (3872 MHz wide, 2000 kHz channels)

16 high resolution SPW (64 MHz wide each, 62.5 kHz channels)



1 low resolution SPW (3872 MHz wide, 2000 kHz channels)

4 high resolution SPW
(widths: 384, 192, 320, 128 MHz, 62.5 kHz channels)

NOEMA Backend

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- In a given baseband, a **spectral window** is
  a set of contiguous chunks processed at the same spectral resolution
- With the default mode:
  - 1 Correlator Unit output is made of:
    - 1 low resolution spectral window at 2MHz resolution (made of 61 chunks)
    - $1<n_{spw}<16$ high resolution spectral windows at 62.5kHz (made of $16>n_{chunks}>1$ chunks)
- With the 250kHz mode:
  - 1 Correlator Unit output is made of:
    - 1 low resolution spectral window at 2MHz resolution (made of 61 chunks)
      - In that case the low resolution spectral window is obtained by averaging 8 channels of the high resolution spectral window
    - 1 high resolution spectral windows at 250kHz (made of 61 chunks)

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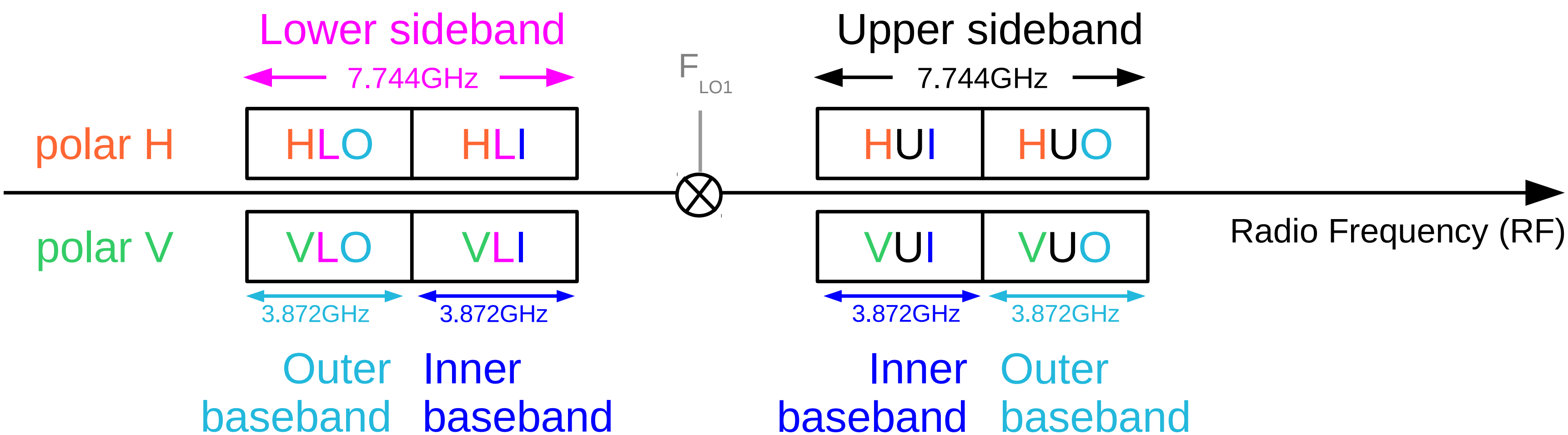
3. Preparing observations in GILDAS\ASTRO

NOEMA Backend

Summary

- Each 4-12 GHz IF output of the receivers split into 2 basebands (0-4GHz IF2)



- 8 Basebands (0-4GHz) feed 8 Correlator units

	1 Unit	All Units
Default Mode Continuum + Lines	61 chunks (3872 MHz) at 2 MHz resolution **AND** 16 chunks at 62.5 kHz resolution*	~16 GHz x 2 polar with 2 MHz channels **AND** 8 GHz with 62.5kHz channels*
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*High resolution chunks chosen among the 61 of the **fixed** filter bank

How to prepare NOEMA spectral setups ?

Need for software tools to visualize frequency coverage

- New receivers and correlator
- Increased complexity and flexibility

Need for a tool to set the receiver/correlator configuration when preparing a proposal

- Old (pre-PolyFiX) way of configuring Narrow Band in the proposal management system is not satisfactory for up to 128 high resolution spectral windows.

Everything in the Gildas package ASTRO (feb17 and later releases)

- New commands implemented
  - Set up the hardware configuration
  - Visualize the frequency coverage
  - Follow the usage of resources
  - Export a script to be uploaded to the proposal management system

NOEMA Setups in ASTRO

Use ASTRO in Gildas

```
$astro
OBSERVATORY NOEMA
TIME
```

Define a source (with a given velocity or redshift)

```
SOURCE
```

Define a receiver band tuning

```
TUNING
```

Select a/some baseband(s) + associated correlator mode

```
BASEBAND
```

Define flexible spectral windows (in the selected BB)

- Select the 16 high resolution chunks

```
SPW
```

Examine my current settings

```
LIST
PLOT
```

Remove a spectral window

```
RESET
```

Get a final script (to be uploaded @ pms/iram.fr)

```
PROPOSAL /FILE
```

Other useful commands:

Get some help

```
HELP COMMAND
```

Show molecular lines on frequency plots

```
SET LINES ON
```

Choose line profile to be drawn

```
SET LINES GAUSS 100
```

Change the catalog of lines

```
CATALOG Myfile.lin /LINE
```

Choose the frequency axis

```
SET FREQUENCY Main Second
```

Prepare interlaced tunings

```
SPECSWEEP command (see HELP)
```

NOEMA setups in ASTRO

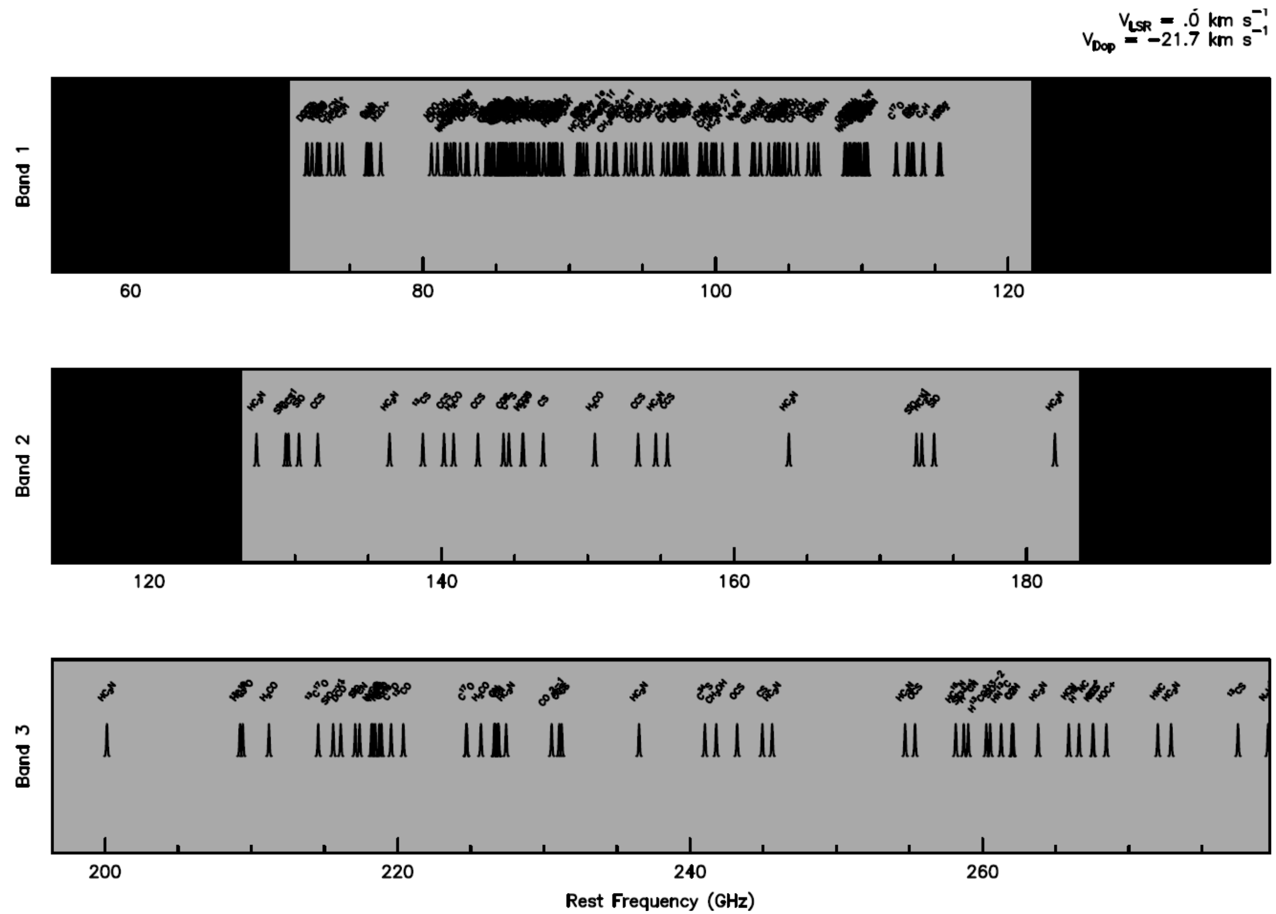
Prepare the environment:

```
OBSERVATORY NOEMA
TIME 00:00:00.0 20-OCT-2016

SOURCE MySource EQ 2000 10:00:00.0 20:00:00.0 LSR 0
    MySource    Azimuth -121.78699    Elevation  -2.75186
    MySource    V(S/OBS) =   -21.668 [S/LSR=  0.000,LSR/G=  4.952,G/OBS=-26.620]
    MySource    Redshift      0.000
! Full SOURCE can be entered to enable Doppler computations
SOURCE /DOPPLER LSR 100 or SOURCE /DOPPLER REDSHIFT 0.5
! to take into account a typical LSR or Redshift without additionnal
Doppler computations (i.e. No Earth or Observatory contribution)

SET LINES GAUSS 100
! Lines from the catalog will be indicated by a gaussian (width=100MHz)
```

NOEMA setups in ASTRO

Define the receiver tuning

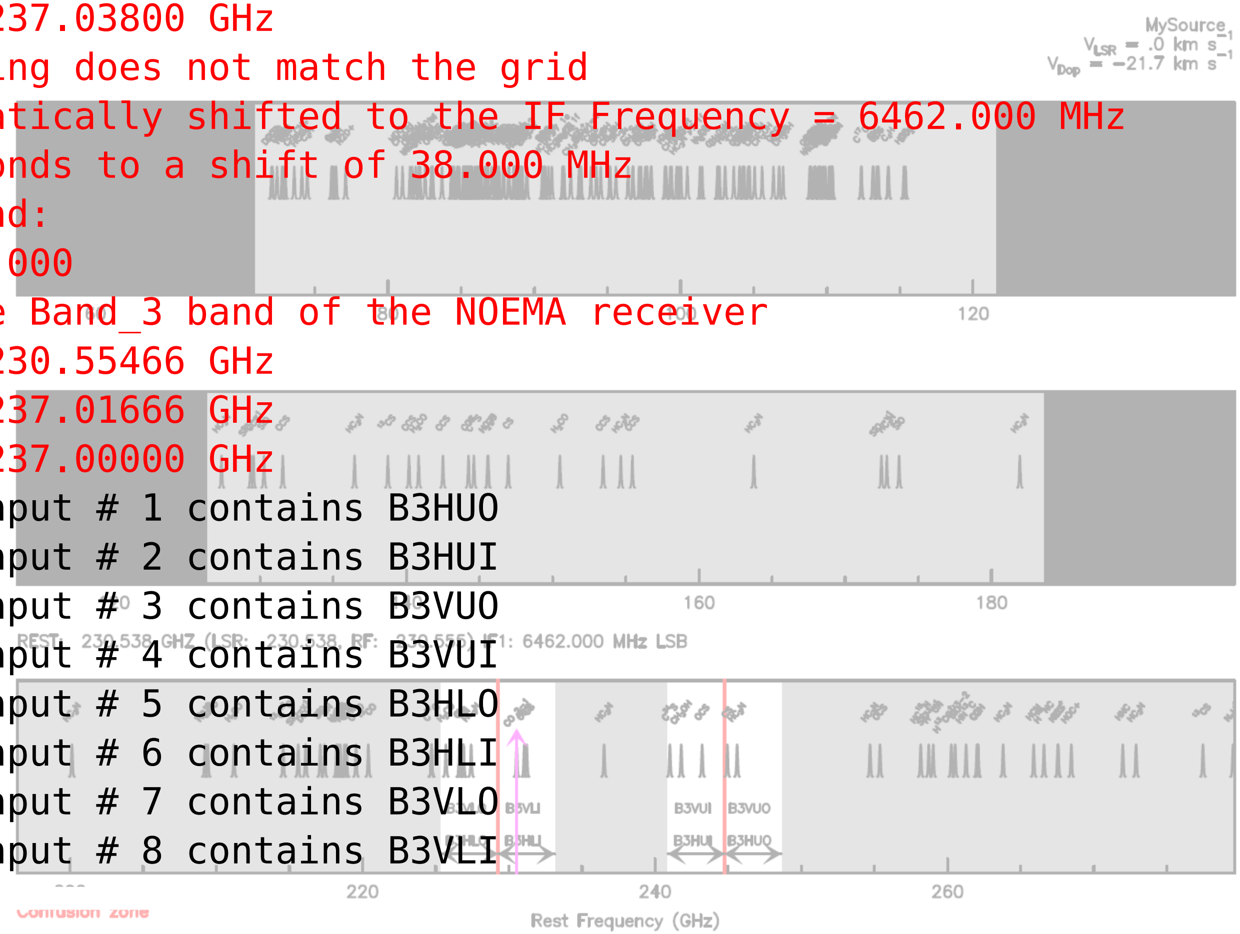
```
TUNING ! Display the coverage of available receiver bands
       ! Nothing actually DONE, only plot
   I-TUNING,  Showing the coverage of NOEMA receiver bands
TUNING /INFO ! Returns main receiver characteristics
```



NOEMA setups in ASTRO

Define the receiver tuning

```
TUNING ! Display the coverage of available receiver bands
TUNING 230.538 LSB 6500 ! tune 230.538 REST at 6500 IF1 in LSB
    I-TUNING,  Resetting tuning
    I-TUNING,  Selecting the Band_3 band of the NOEMA receiver
    I-TUNING,   FRF     =  230.55466 GHz
    I-TUNING,   FLO1    =  237.05466 GHz
    I-TUNING,   FLOTUNE =  237.03800 GHz
    I-TUNING,  Original tuning does not match the grid
    I-TUNING,  Tuning automatically shifted to the IF Frequency = 6462.000 MHz
    I-TUNING,  This corresponds to a shift of 38.000 MHz
    I-TUNING,  Actual command:
    TUNING 230.538 LSB 6462.000
    I-TUNING,  Selecting the Band_3 band of the NOEMA receiver
    I-TUNING,   FRF     =  230.55466 GHz
    I-TUNING,   FLO1    =  237.01666 GHz
    I-TUNING,   FLOTUNE =  237.00000 GHz
    I-TUNING,  Correlator input # 1 contains B3HUO
    I-TUNING,  Correlator input # 2 contains B3HUI
    I-TUNING,  Correlator input # 3 contains B3VUO
    I-TUNING,  Correlator input # 4 contains B3VUI
    I-TUNING,  Correlator input # 5 contains B3HLO
    I-TUNING,  Correlator input # 6 contains B3HLI
    I-TUNING,  Correlator input # 7 contains B3VLO
    I-TUNING,  Correlator input # 8 contains B3VLI
```



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    I-TUNING,  Original tur
    I-TUNING,  Tuning autom
    I-TUNING,  This corresp
    I-TUNING,  Actual comma
    TUNING 230.538 LSB 646
    I-TUNING,  Selecting th
    I-TUNING,   FRF     =
    I-TUNING,   FLO1    =
    I-TUNING,   FLOTUNE =
    I-TUNING,  Correlator i
    I-TUNING,  Correlator i
    I-TUNING,  Correlator i
    I-TUNING,  Correlator i
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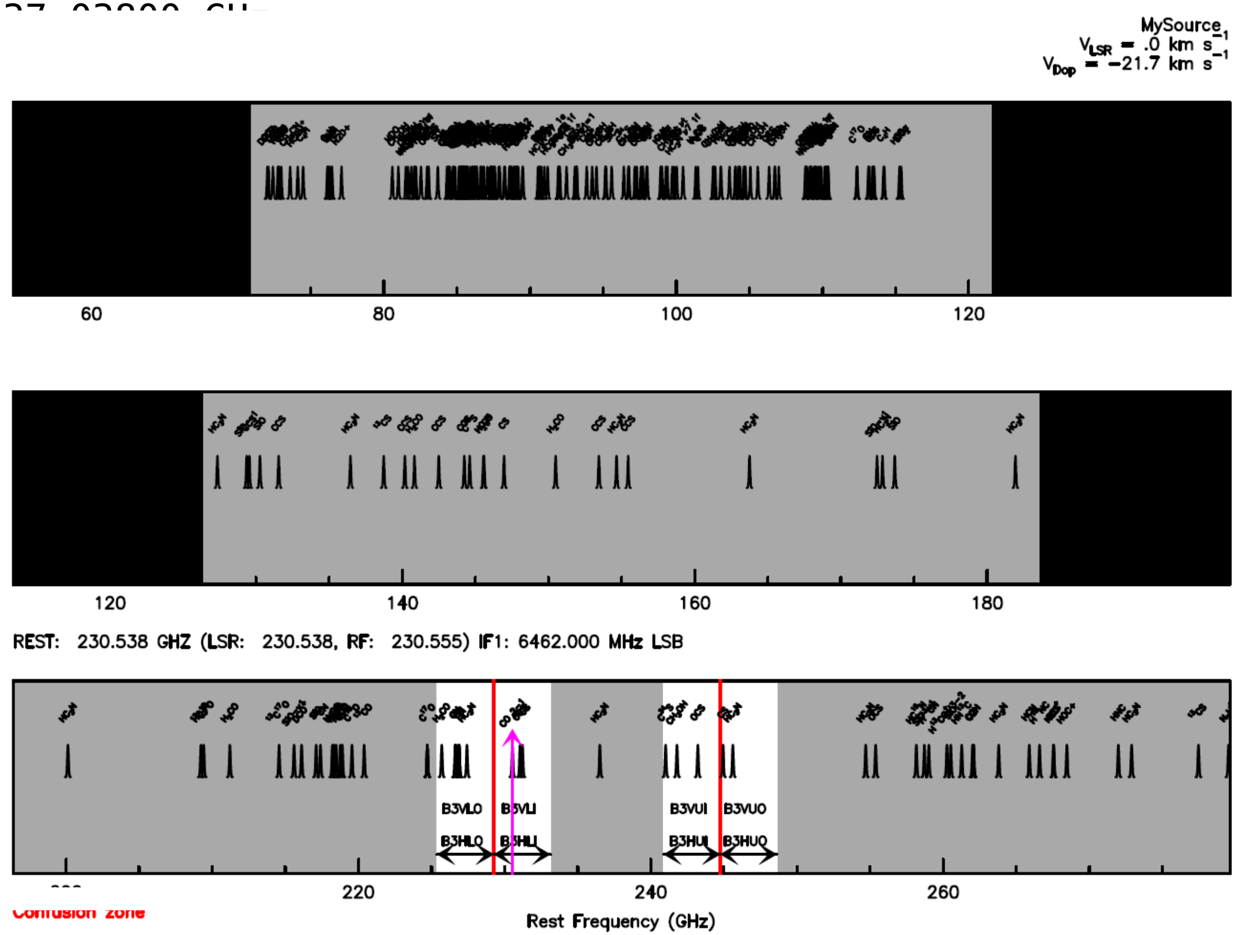
```



NOEMA setups in ASTRO

Define the receiver tuning

```
TUNING ! Display the coverage of available receiver bands
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    I-TUNING,   FRF     =  230.55466 GHz
    I-TUNING,   FLO1    :
    I-TUNING,   FLOTUNE :
    I-TUNING,  Original
    I-TUNING,  Tuning au
    I-TUNING,  This corr
    I-TUNING,  Actual co
    TUNING 230.538 LSB 6
    I-TUNING,  Selecting
    I-TUNING,   FRF     :
    I-TUNING,   FLO1    :
    I-TUNING,   FLOTUNE :
    I-TUNING,  Correlato
    I-TUNING,  Correlato
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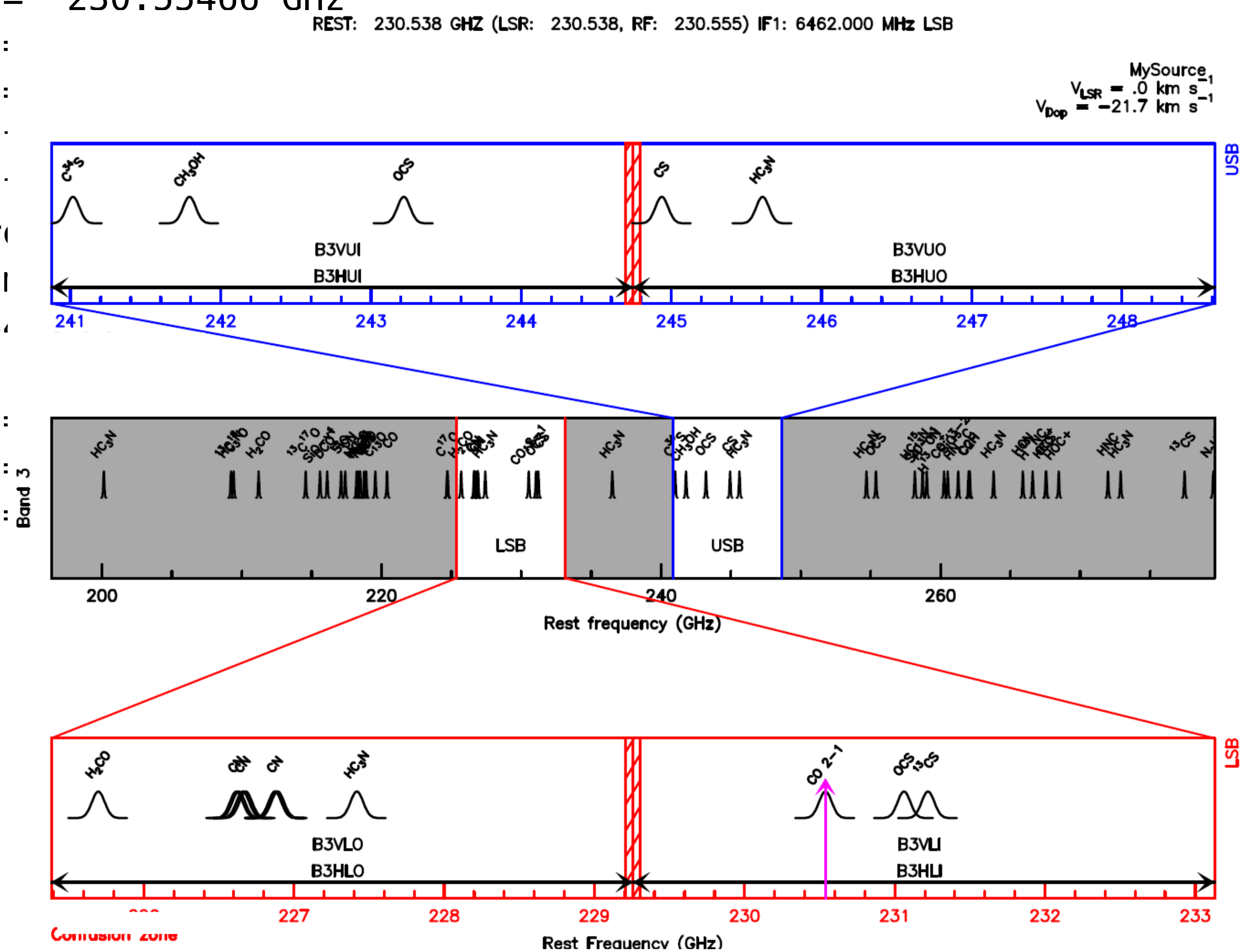


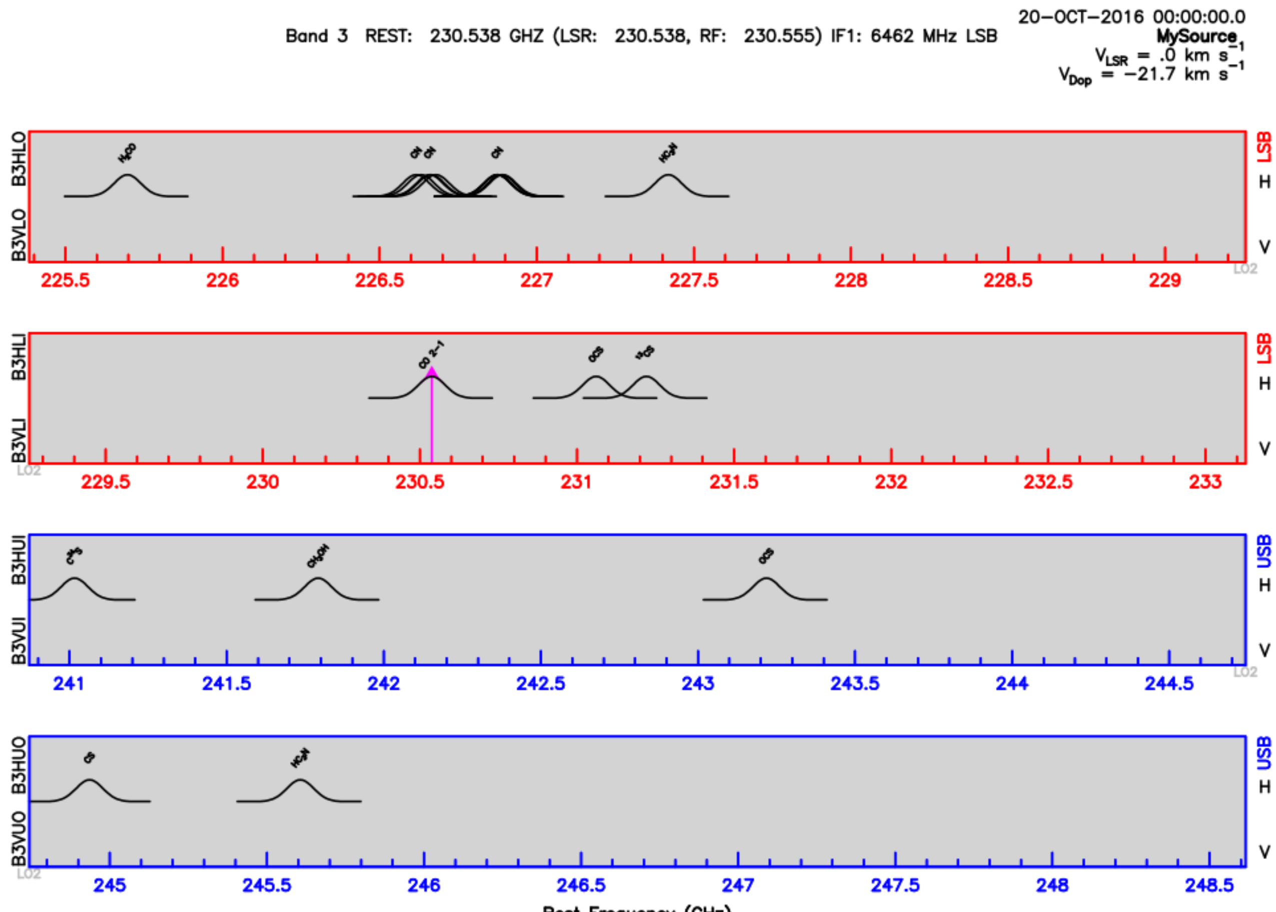
NOEMA setups in ASTRO

Select a/some basebands and assign a correlator mode

```
BASEBAND SelectionCode [/MODE [df1 [df2]]|OFF]
! Selection code = baseband identification: combination of H/V,U/L,O/I
! /MODE option to select a mode
BASEBAND
! No selection restriction: (H+V) x (U+L) x (O+I) = 8 basebands selected
! No /MODE: no mode applied
!   no SPW created
```

Nota Bene:

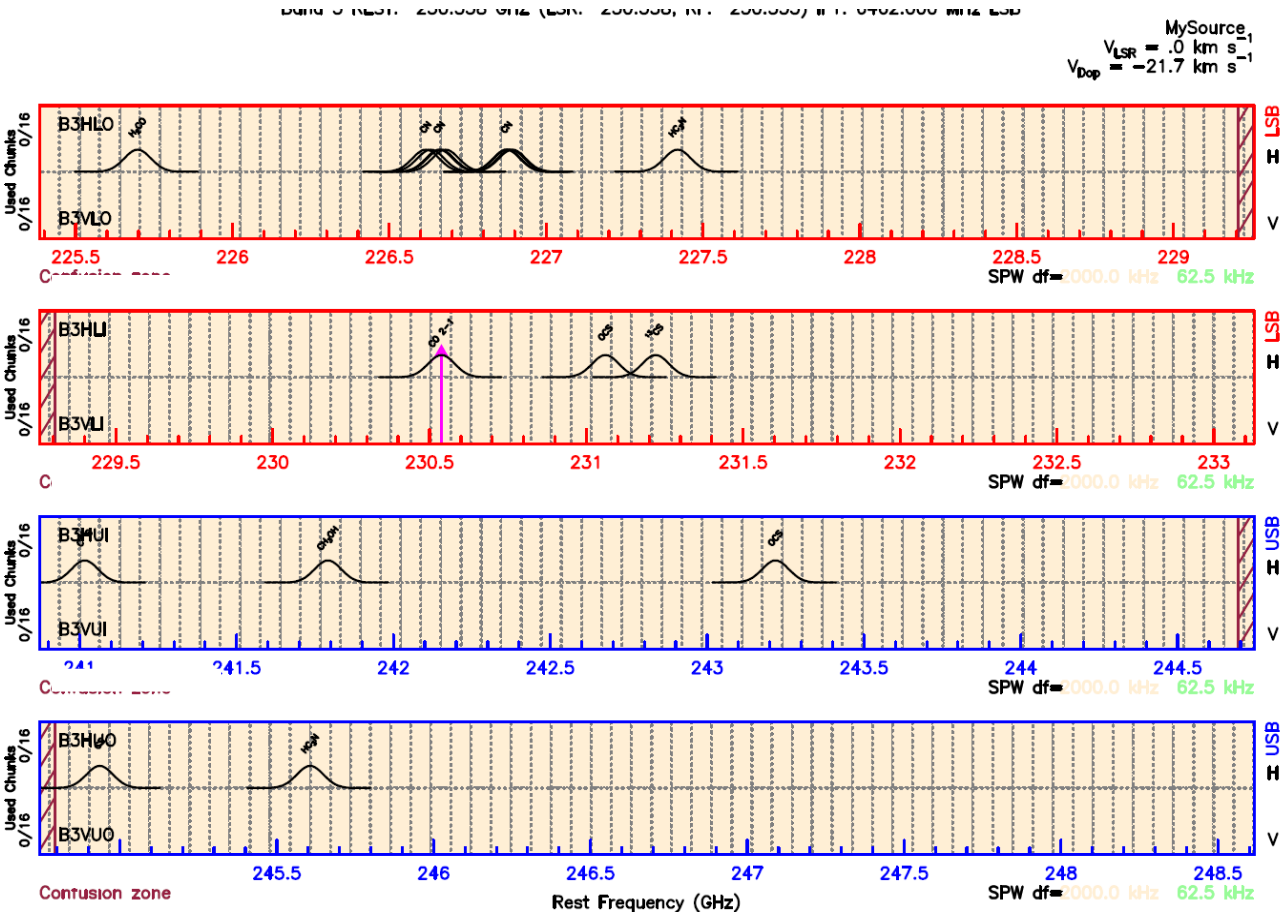
Change of syntax of BASEBAND command as of May21 gildas distribution



NOEMA setups in ASTRO

Select a/some basebands and assign a correlator mode

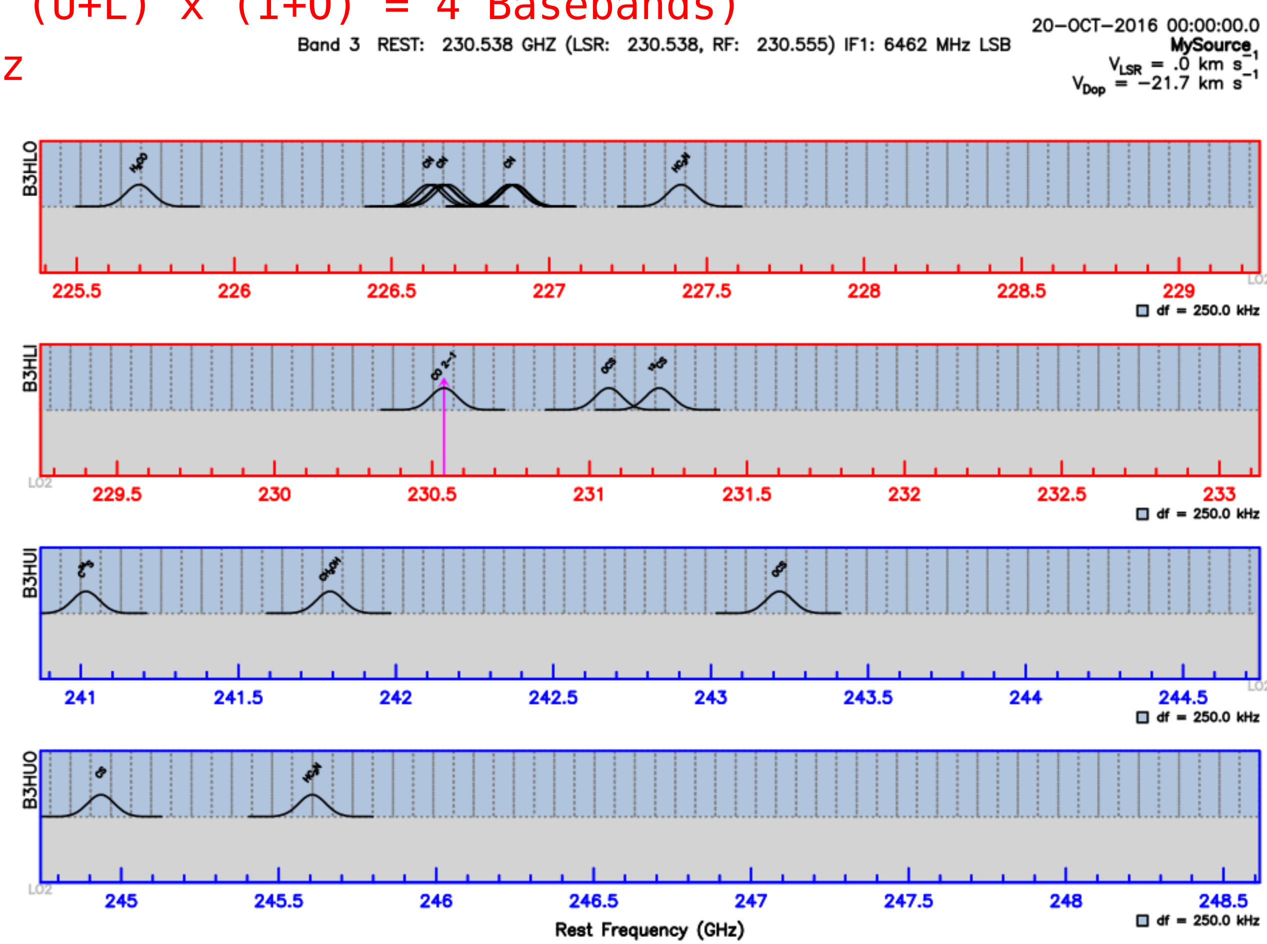
```
BASEBAND SelectionCode [/MODE [df1 [df2]]|OFF]
! Selection code = baseband identification: combination of H/V,U/L,O/I
! /MODE option to select a mode
BASEBAND /MODE 2000 62.5  ! all basebands selected
! 2000 62.5 = Continuum+Line mode
! Low res SPW created
```



NOEMA setups in ASTRO

Select a/some basebands and assign a correlator mode

```
BASEBAND SelectionCode [/MODE [df1 [df2]]|OFF]
! Selection code = baseband identification: combination of H/V,U/L,O/I
! /MODE option to select a mode
BASEBAND /MODE 2000 62.5  ! all basebands selected, mode cont+line
BASEBAND H /MODE 250
! H polar selected (H x (U+L) x (I+O) = 4 Basebands)
! Mode full bb at 250kHz
! V polar not touched
```



NOEMA setups in ASTRO

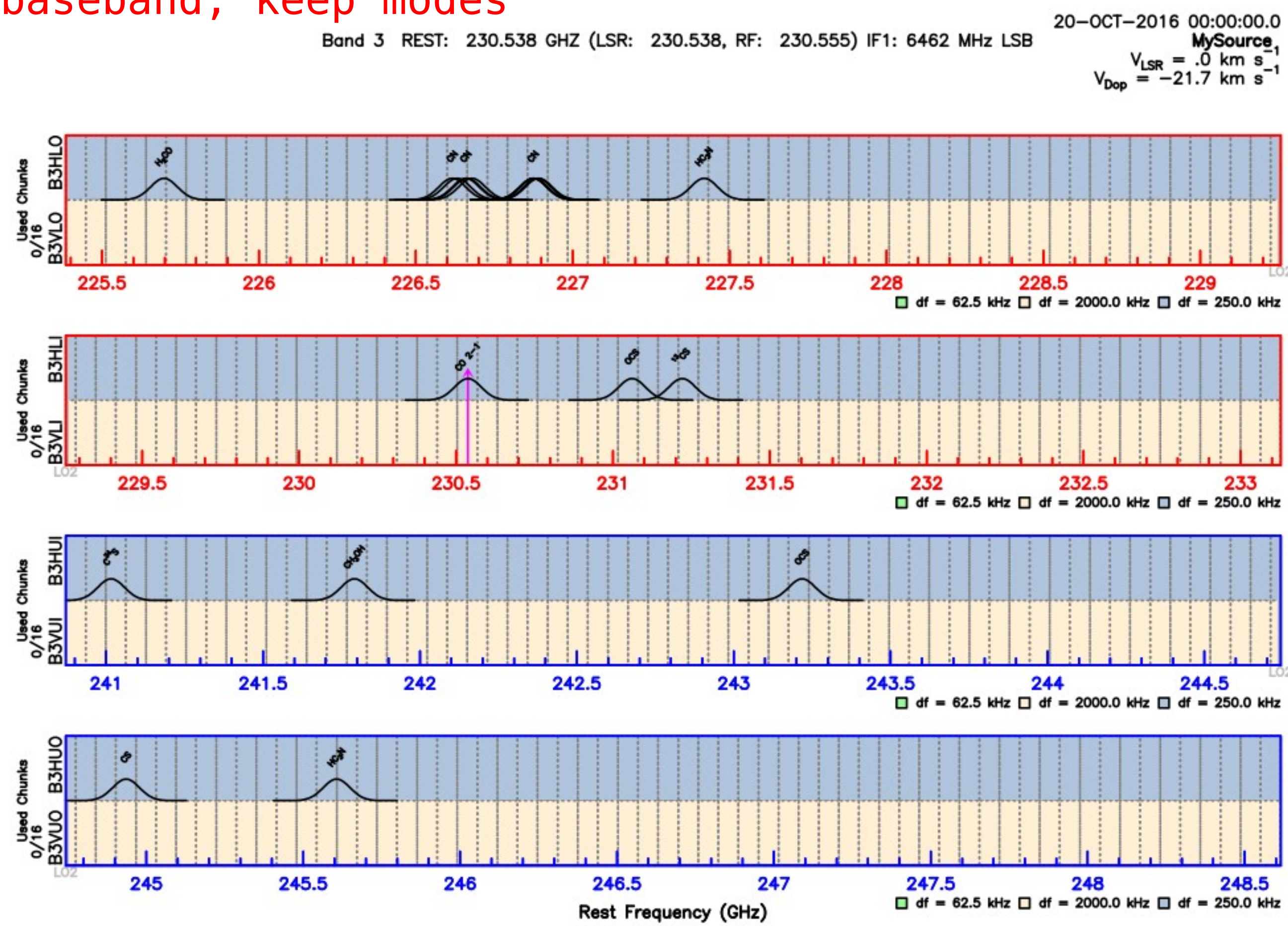
Select a/some basebands and assign a correlator mode

```
BASEBAND SelectionCode [/MODE [df1 [df2]]|OFF]
! Selection code = baseband identification: combination of H/V,U/L,O/I
! /MODE option to select a mode
BASEBAND /MODE 2000 62.5  ! all basebands selected, mode cont+line
BASEBAND H /MODE 250! H polar selected, Mode full bb at 250kHz
BASEBAND ! Select all baseband, keep modes
```

Nota Bene:

In the first implementation of the 250kHz mode, all basebands should use the same correlator mode.

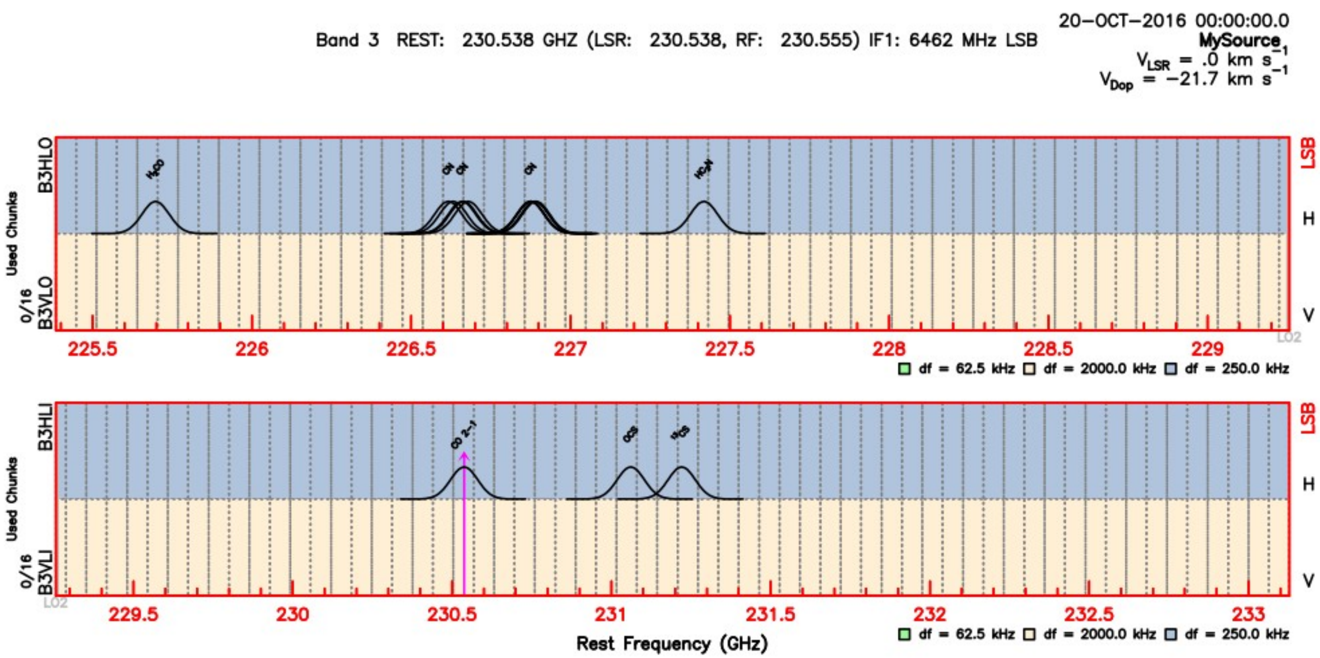
The configuration in this plot cannot be inserted in a proposal



NOEMA setups in ASTRO

Select a/some basebands and assign a correlator mode

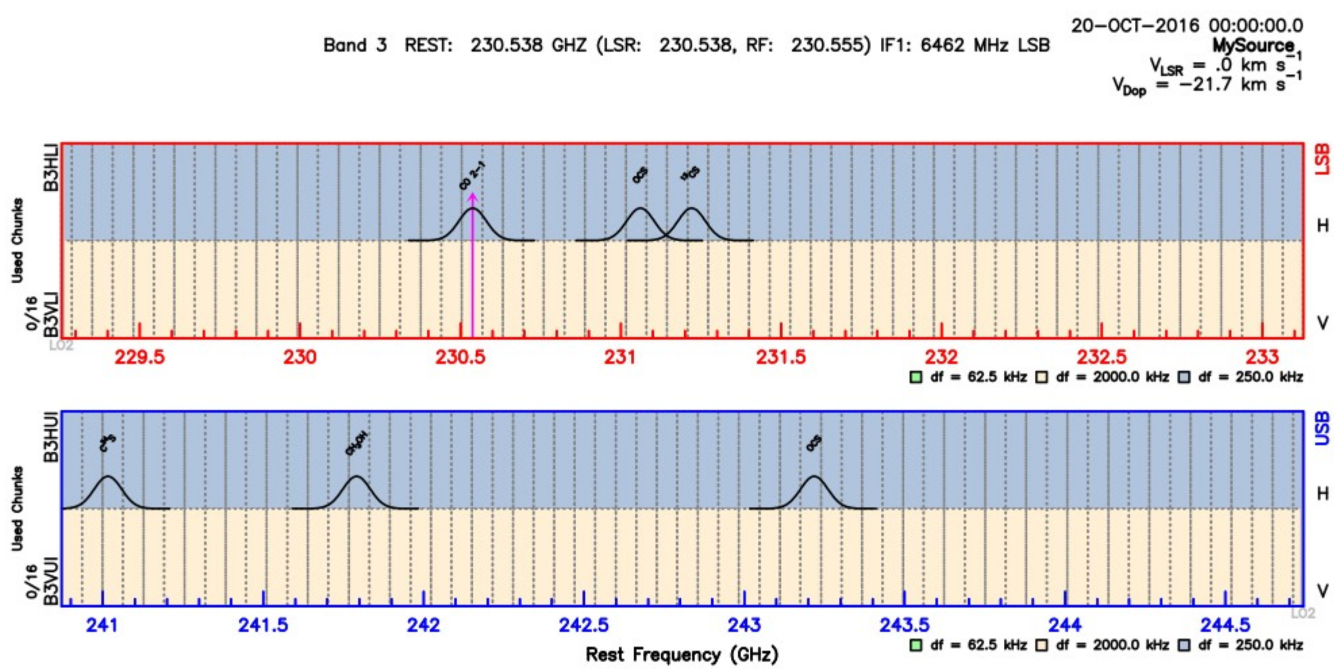
```
BASEBAND SelectionCode [/MODE [df1 [df2]]|OFF]
! Selection code = baseband identification: combination of H/V,U/L,O/I
! /MODE option to select a mode
BASEBAND /MODE 2000 62.5  ! all basebands selected, mode cont+line
BASEBAND H /MODE 250! H polar selected, Mode full bb at 250kHz
BASEBAND ! Select all baseband, keep modes
BASEBAND L ! Lower sideband: (H+V) x L x (I+O) = 4 Basebands, keep modes
```



NOEMA setups in ASTRO

Select a/some basebands and assign a correlator mode

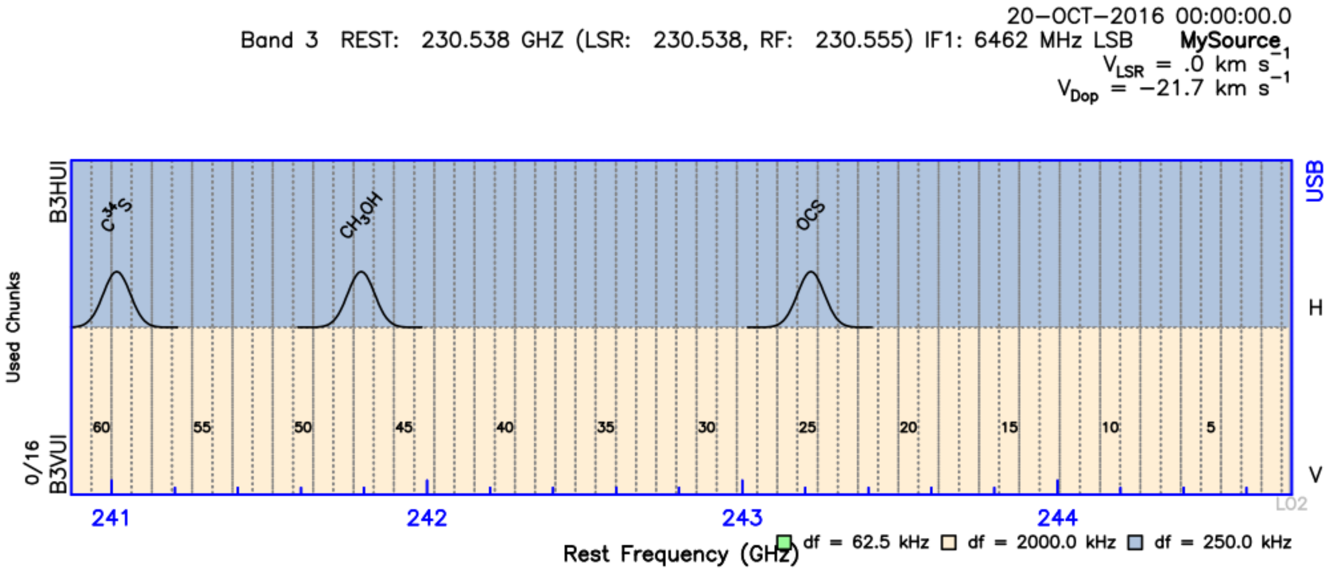
```
BASEBAND SelectionCode [/MODE [df1 [df2]]|OFF]
! Selection code = baseband identification: combination of H/V,U/L,O/I
! /MODE option to select a mode
BASEBAND /MODE 2000 62.5  ! all basebands selected, mode cont+line
BASEBAND H /MODE 250! H polar selected, Mode full bb at 250kHz
BASEBAND ! Select all baseband, keep modes
BASEBAND L ! Lower sideband: (H+V) x L x (I+O) = 4 Basebands, keep modes
BASEBAND I ! Inner basebands: (H+V) x (L+U) x I = 4 Basebands, keep modes
```



NOEMA setups in ASTRO

Select a/some basebands and assign a correlator mode

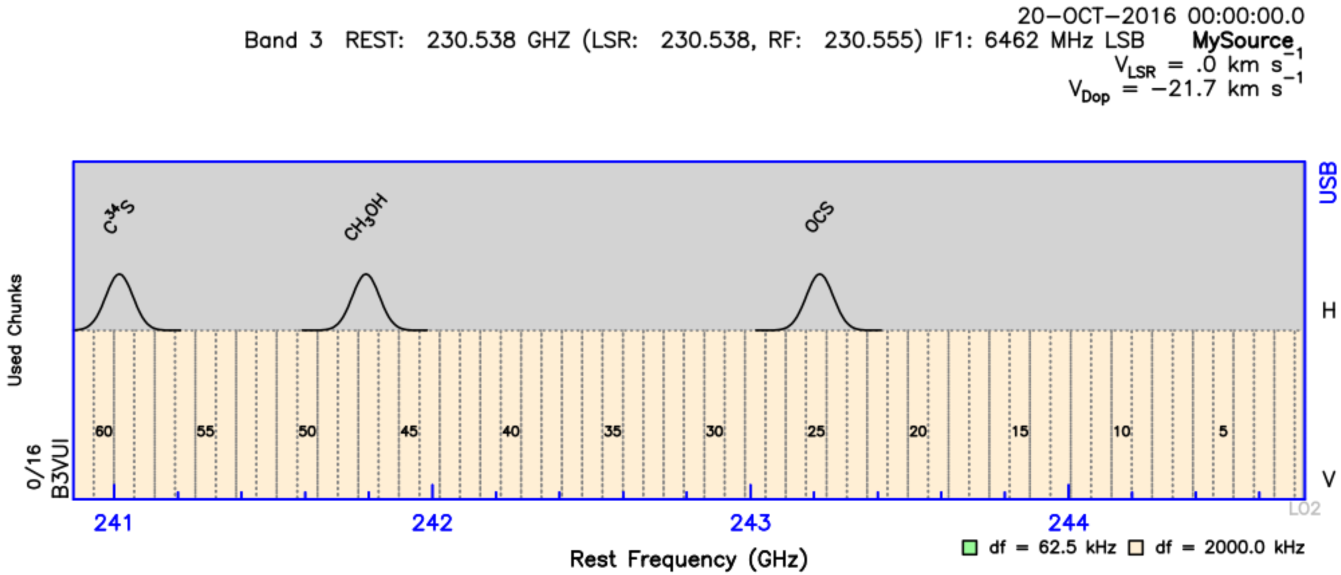
```
BASEBAND SelectionCode [/MODE [df1 [df2]]|OFF]
! Selection code = baseband identification: combination of H/V,U/L,O/I
! /MODE option to select a mode
BASEBAND /MODE 2000 62.5  ! all basebands selected, mode cont+line
BASEBAND H /MODE 250! H polar selected, Mode full bb at 250kHz
BASEBAND ! Select all baseband, keep modes
BASEBAND L ! Lower sideband: (H+V) x L x (I+O) = 4 Basebands, keep modes
BASEBAND I ! Inner basebands: (H+V) x (L+U) x I = 4 Basebands, keep modes
BASEBAND UI ! USB, Inner BB: (H+V) x U x I = 2 Basebands, keep modes
```



NOEMA setups in ASTRO

Select a/some basebands and assign a correlator mode

```
BASEBAND SelectionCode [/MODE [df1 [df2]]|OFF]
! Selection code = baseband identification: combination of H/V,U/L,O/I
! /MODE option to select a mode
BASEBAND /MODE 2000 62.5  ! all basebands selected, mode cont+line
BASEBAND H /MODE 250! H polar selected, Mode full bb at 250kHz
BASEBAND ! Select all baseband, keep modes
BASEBAND L ! Lower sideband: (H+V) x L x (I+O) = 4 Basebands, keep modes
BASEBAND I ! Inner basebands: (H+V) x (L+U) x I = 4 Basebands, keep modes
BASEBAND UI ! USB, Inner BB: (H+V) x U x I = 2 Basebands, keep modes
BASEBAND VUI ! Polar V, USB, Inner BB: V x U x I = 1 Baseband, keep modes
```



NOEMA setups in ASTRO

Define Spectral Windows

```
BASEBAND /MODE 2000 62.5 ! Only mode available now applied to all BB
BASEBAND VUI ! 1 baseband selected
SPW /FREQUENCY 243.25 0.3
! 1 SPW covering a range centered at 243.25 with a width of 300 MHz
    I-SPW,  SPW fits in unit 4 B3VUI
    I-SPW,  Spectral window covers chunks 22 to 27
    I-SPW,  Unit B3VUI High_Res is used at 38%
LIST
    I-LIST,  9 spectral windows defined:
    SPW  1 in B3HLO: df = 2000.000 kHz, Chunks  1 to 61, REST  225384.37 to 229256.09 MHz
    [...]
    SPW  8 in B3VUO: df = 2000.000 kHz, Chunks  1 to 61, REST  244742.97 to  248614.69 MHz
    SPW  9 in B3VUI: df =   62.500 kHz, Chunks 22 to 27, REST  243047.10 to  243431.07 MHz
```

Nota Bene 1:

The SPW command cannot be used in baseband defined with the 250 kHz mode

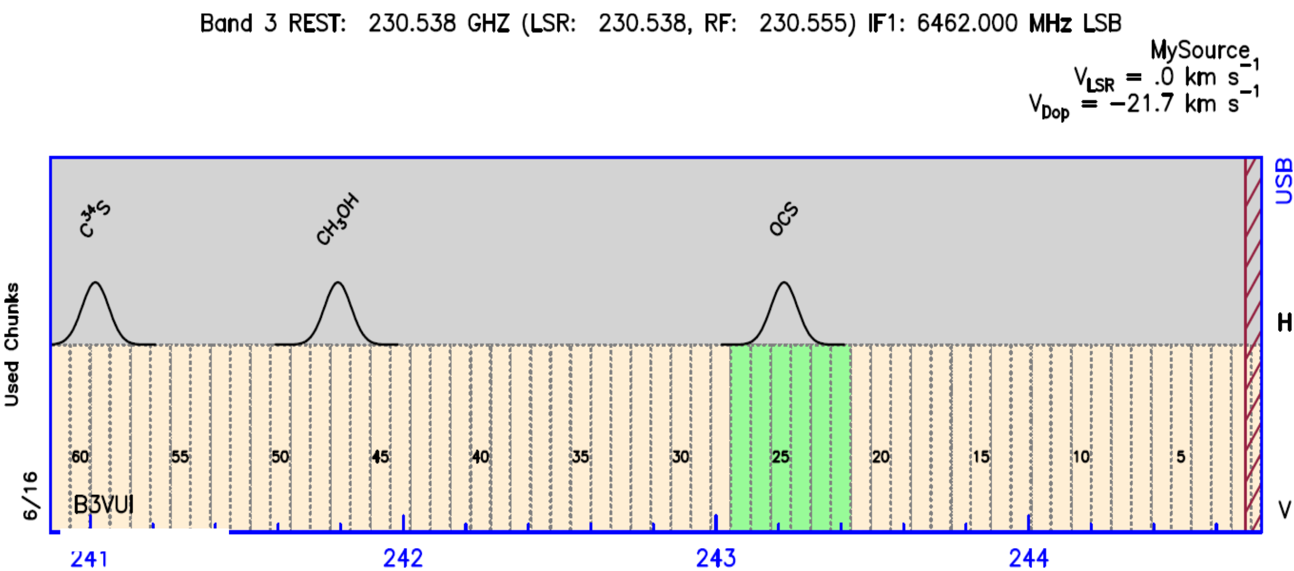
Nota Bene 2:

Actual coverage is not exactly 300 MHz

(6 x 64=384 MHz)

The system uses the chunks necessary to cover the requested range

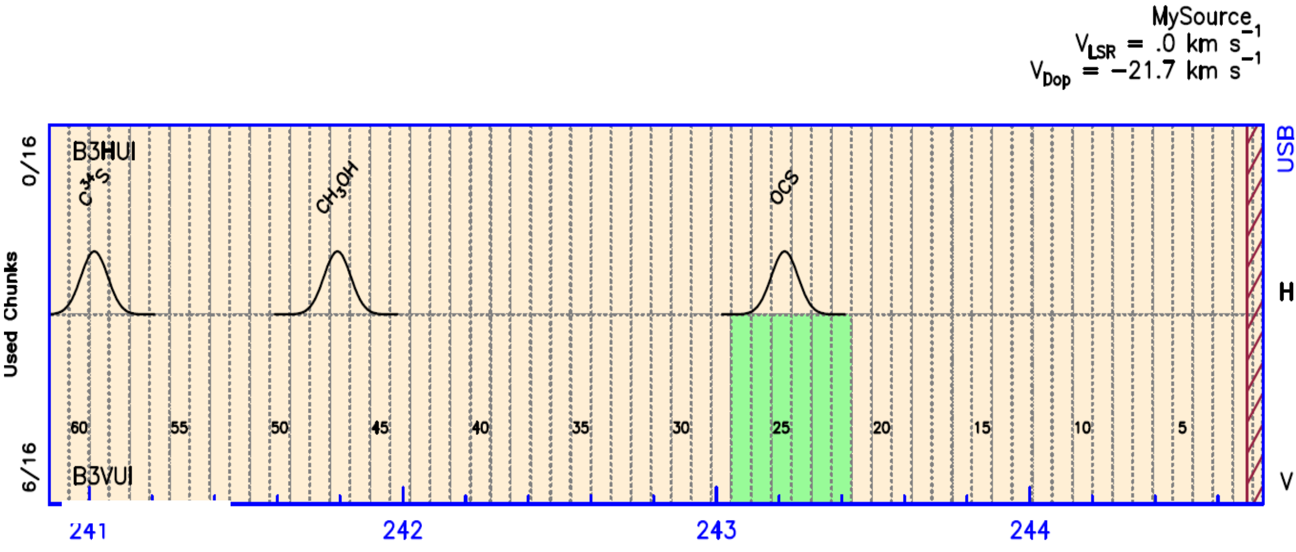
Chunks are on a fixed grid, with a fixed width



NOEMA setups in ASTRO

Define Spectral Windows

BASEBAND UI



NOEMA setups in ASTRO

Define Spectral Windows

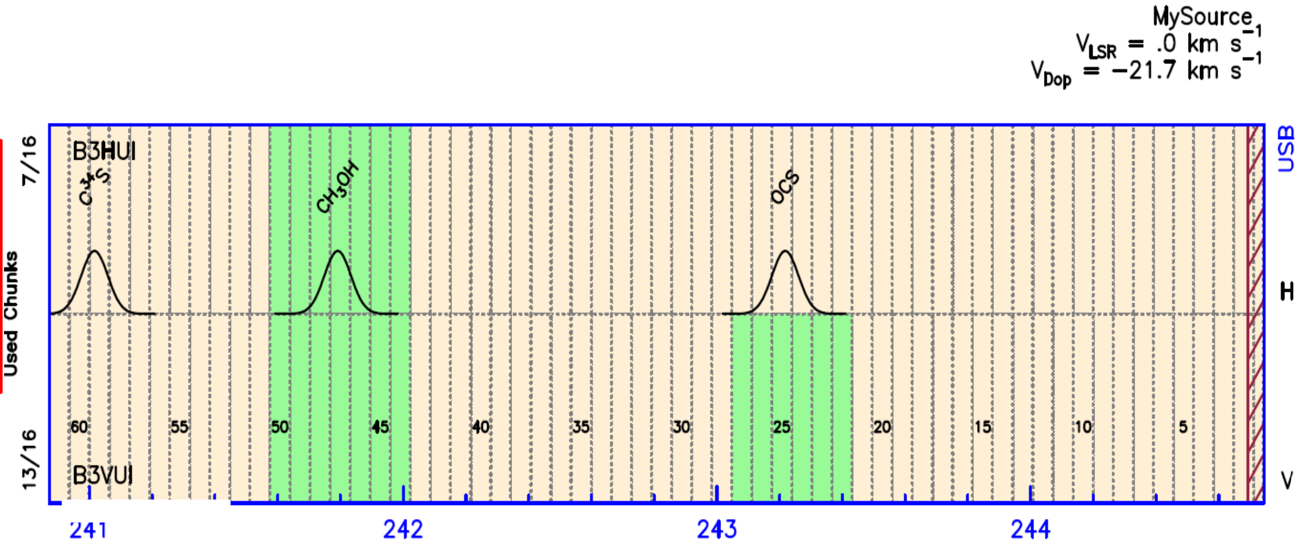
```
BASEBAND UI
SPW /RANGE 241.6 242 ! SPW from 241.6 to 242 in H and V (2SPW)
    I-SPW,  SPW fits in unit 2 B3HUI
    I-SPW,  Spectral window covers chunks 44 to 50
    I-SPW,  Unit B3HUI High_Res is used at 44%
    I-SPW,  SPW fits in unit 4 B3VUI
    I-SPW,  Spectral window covers chunks 44 to 50
    I-SPW,  Unit B3VUI High_Res is used at 81%
LIST
    I-LIST, 11 spectral windows defined:
    [...]SPW  1 in B3HLO: df = 2000.000 kHz, Chunks  1 to 61, REST  225384.37 to 229256.09 MHz
    SPW  8 in B3VUO: df = 2000.000 kHz, Chunks  1 to 61, REST  244742.97 to  248614.69 MHz
    SPW  9 in B3HUI: df =   62.500 kHz, Chunks 44 to 50, REST  241575.20 to  242023.17 MHz
    SPW 10 in B3VUI: df =   62.500 kHz, Chunks 44 to 50, REST  241575.20 to  242023.17 MHz
    SPW 11 in B3VUI: df =   62.500 kHz, Chunks 22 to 27, REST  243047.10 to  243431.07 MHz
```

Nota Bene:

Actual SPW width is not exactly 400 MHz

(7 x 64 = 448 MHz)

Chunks are on a fixed grid, with a fixed width



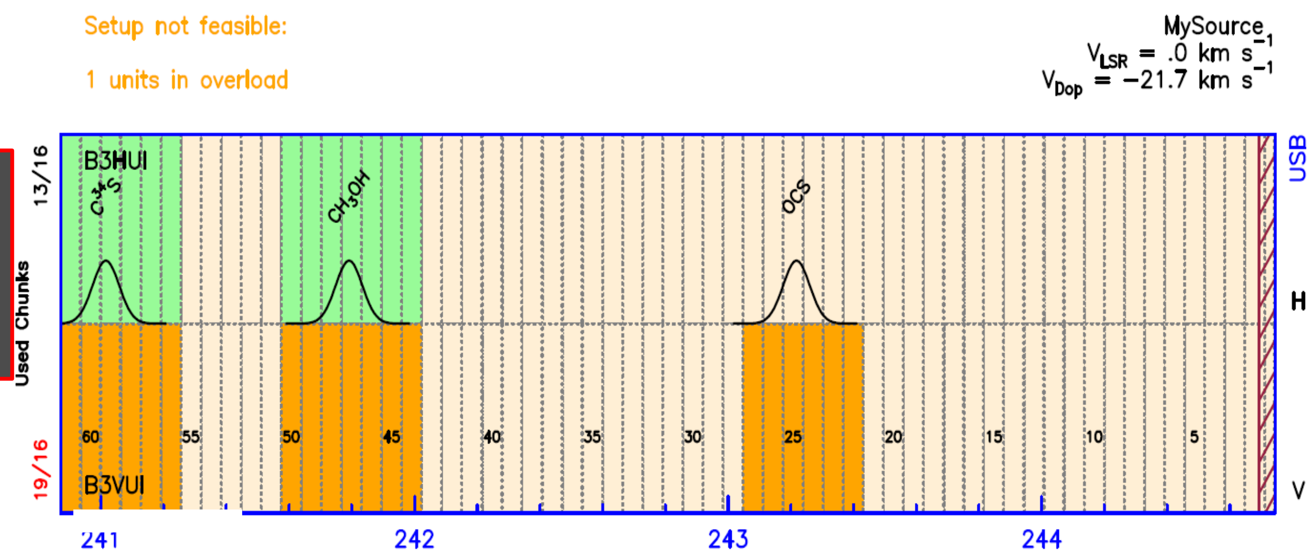
NOEMA setups in ASTRO

Define Spectral Windows

```
BASEBAND UI
SPW /CHUNK 56 to 61 ! 2 SPW defined by chunk numbers
    I-SPW,  Unit B3HUI High_Res is used at 81%
    I-SPW,  Unit B3VUI High_Res is used at 119%
    W-SPW,  You are using more resources than available
! Setup using more than 16 high res chunks in VUI
```

Nota Bene:

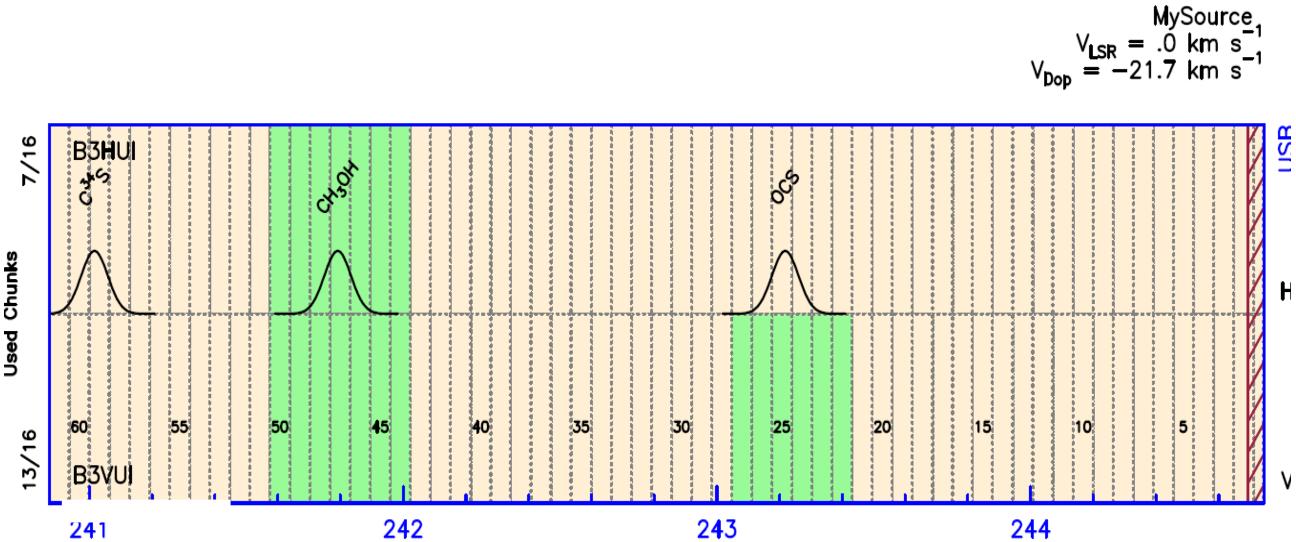
/CHUNK option available only when the baseband selection contains only 1 frequency range (eventually dual polars)



NOEMA setups in ASTRO

Define Spectral Windows

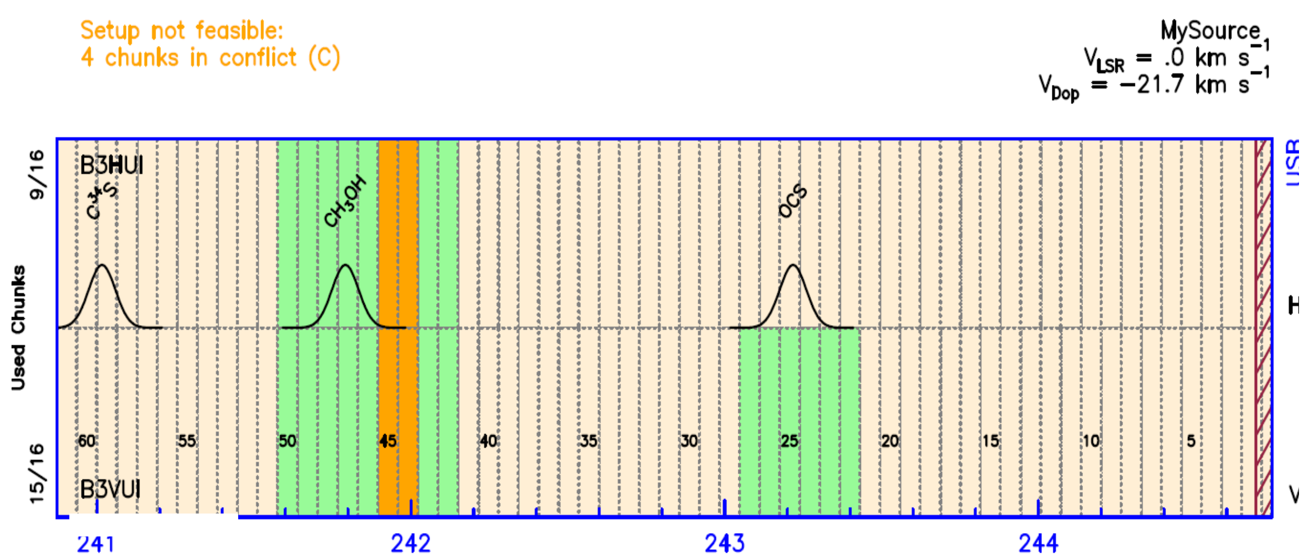
```
BASEBAND UI
SPW /CHUNK 56 to 61 ! 2 SPW defined by chunk numbers
    I-SPW,  Unit B3HUI High_Res is used at 81%
    I-SPW,  Unit B3VUI High_Res is used at 119%
    W-SPW,  You are using more resources than available
! Setup using more than 16 high res chunks in VUI
RESET LAST
    I-RESET,  Resetting Spectral Window # 10
    I-RESET,  Resetting Spectral Window # 9
    I-LIST,  11 spectral windows defined:
    SPW  1 in B3HLO: df = 2000.000 kHz, Chunks  1 to 61, REST  225384.37 to  229256.09 MHz
    [...]
    SPW  9 in B3HUI: df =   62.500 kHz, Chunks 44 to 50, REST  241575.20 to  242023.17 MHz
    SPW 10 in B3VUI: df =   62.500 kHz, Chunks 44 to 50, REST  241575.20 to  242023.17 MHz
    SPW 11 in B3VUI: df =   62.500 kHz, Chunks 22 to 27, REST  243047.10 to  243431.07 MHz
```



NOEMA setups in ASTRO

Define Spectral Windows

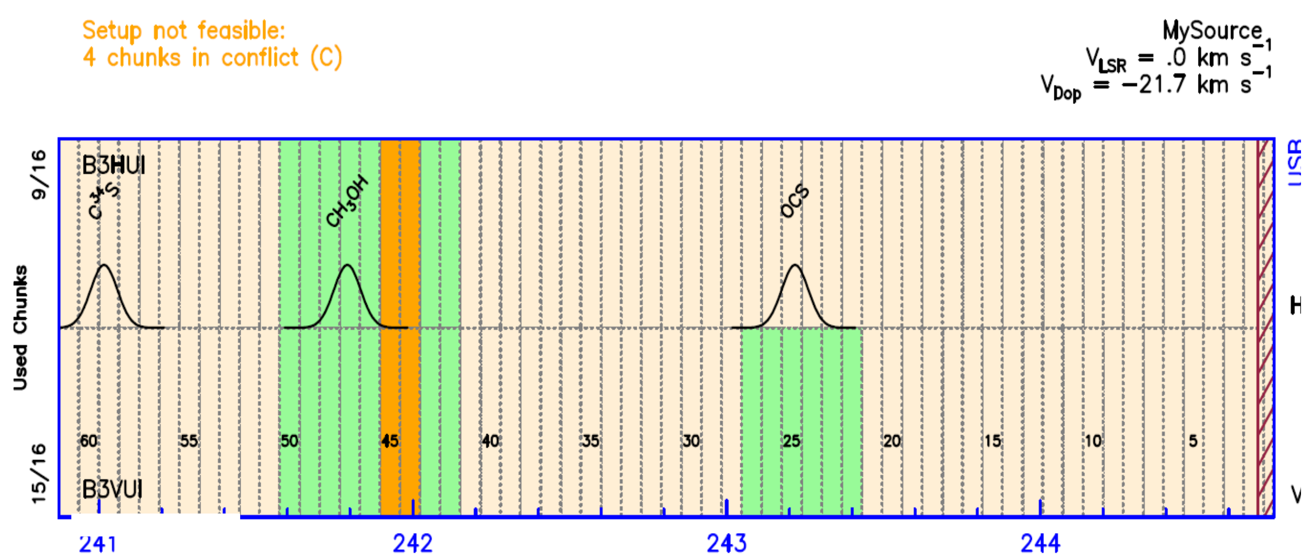
```
BASEBAND UI
SPW /CHUNK 42 to 45
    I-SPW,  Unit B3HUI High_Res is used at 56%
    I-SPW,  Unit B3VUI High_Res is used at 94%
    W-SPW,  SPW #9 uses conflicting chunk(s)
    W-SPW,  SPW #10 uses conflicting chunk(s)
    W-SPW,  SPW #11 uses conflicting chunk(s)
    W-SPW,  SPW #12 uses conflicting chunk(s)
! Setup using several times the same chunks
```



NOEMA setups in ASTRO

Define Spectral Windows

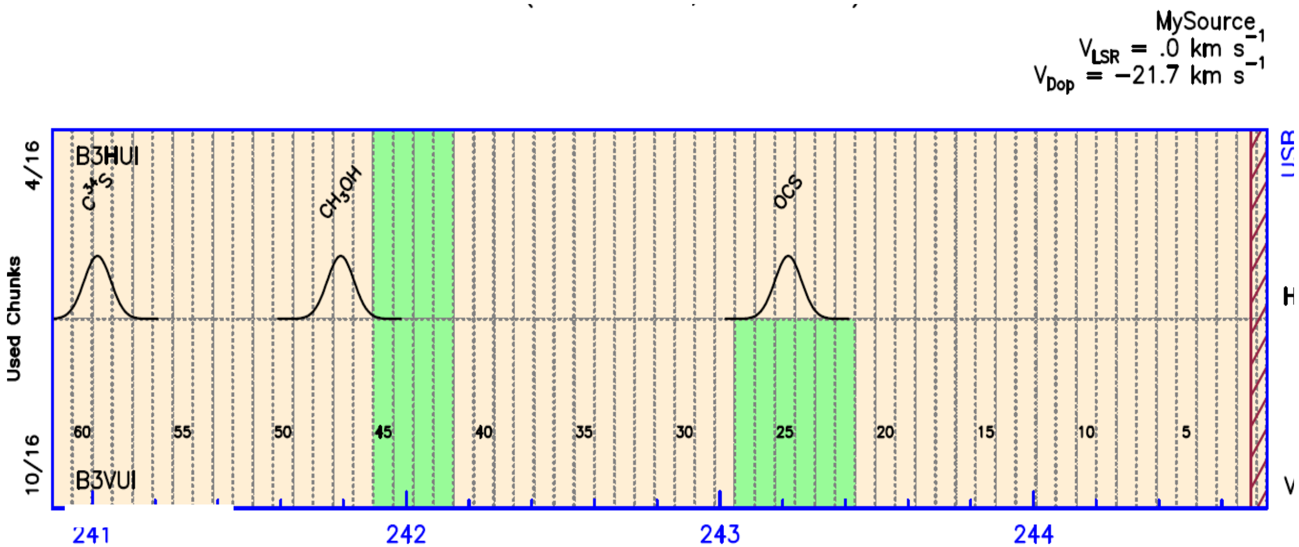
```
BASEBAND UI
SPW /CHUNK 42 to 45
! Setup using several times the same chunks
LIST
[...]
SPW  9 in B3HUI: df =   62.500 kHz, Chunks 44 to 50, REST  241575.20 to  242023.17 MHz !Conflict!
SPW 10 in B3VUI: df =   62.500 kHz, Chunks 44 to 50, REST  241575.20 to  242023.17 MHz !Conflict!
SPW 11 in B3HUI: df =   62.500 kHz, Chunks 42 to 45, REST  241895.18 to  242151.16 MHz !Conflict!
SPW 12 in B3VUI: df =   62.500 kHz, Chunks 42 to 45, REST  241895.18 to  242151.16 MHz !Conflict!
SPW 13 in B3VUI: df =   62.500 kHz, Chunks 22 to 27, REST  243047.10 to  243431.07 MHz
```



NOEMA setups in ASTRO

Define Spectral Windows

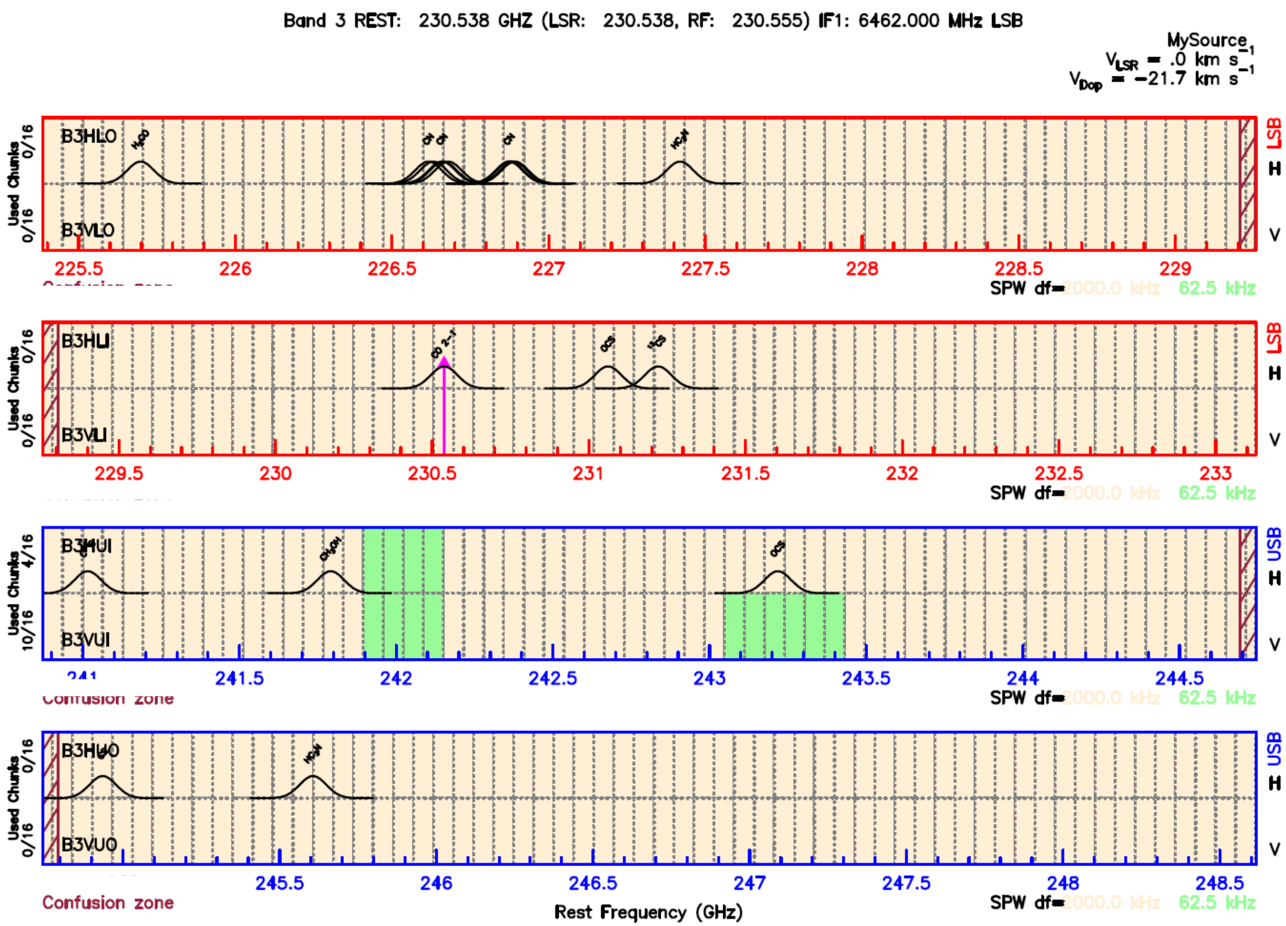
```
BASEBAND UI
SPW /CHUNK 42 to 45
! Setup using several times the same chunks
LIST
[...]
SPW  9 in B3HUI: df =   62.500 kHz, Chunks 44 to 50, REST  241575.20 to  242023.17 MHz !Conflict!
SPW 10 in B3VUI: df =   62.500 kHz, Chunks 44 to 50, REST  241575.20 to  242023.17 MHz !Conflict!
SPW 11 in B3HUI: df =   62.500 kHz, Chunks 42 to 45, REST  241895.18 to  242151.16 MHz !Conflict!
SPW 12 in B3VUI: df =   62.500 kHz, Chunks 42 to 45, REST  241895.18 to  242151.16 MHz !Conflict!
SPW 13 in B3VUI: df =   62.500 kHz, Chunks 22 to 27, REST  243047.10 to  243431.07 MHz
RESET 9 10
[...]
SPW  9 in B3HUI: df =   62.500 kHz, Chunks 42 to 45, REST  241895.18 to  242151.16 MHz
SPW 10 in B3VUI: df =   62.500 kHz, Chunks 42 to 45, REST  241895.18 to  242151.16 MHz
SPW 11 in B3VUI: df =   62.500 kHz, Chunks 22 to 27, REST  243047.10 to  243431.07 MHz
```



NOEMA setups in ASTRO

Visualize current state

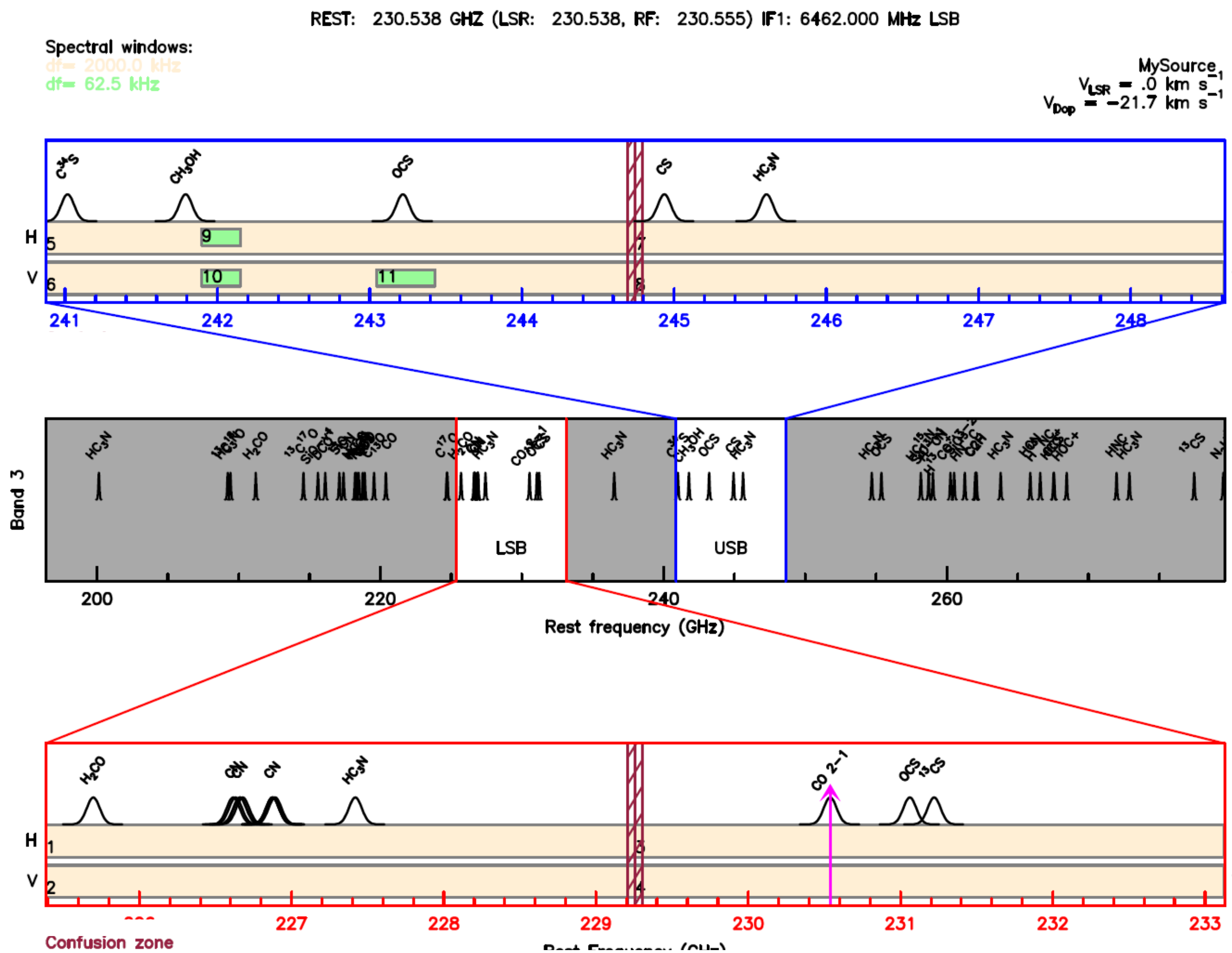
```
PLOT
PLOT /RECEIVER
```



NOEMA setups in ASTRO

Visualize current state

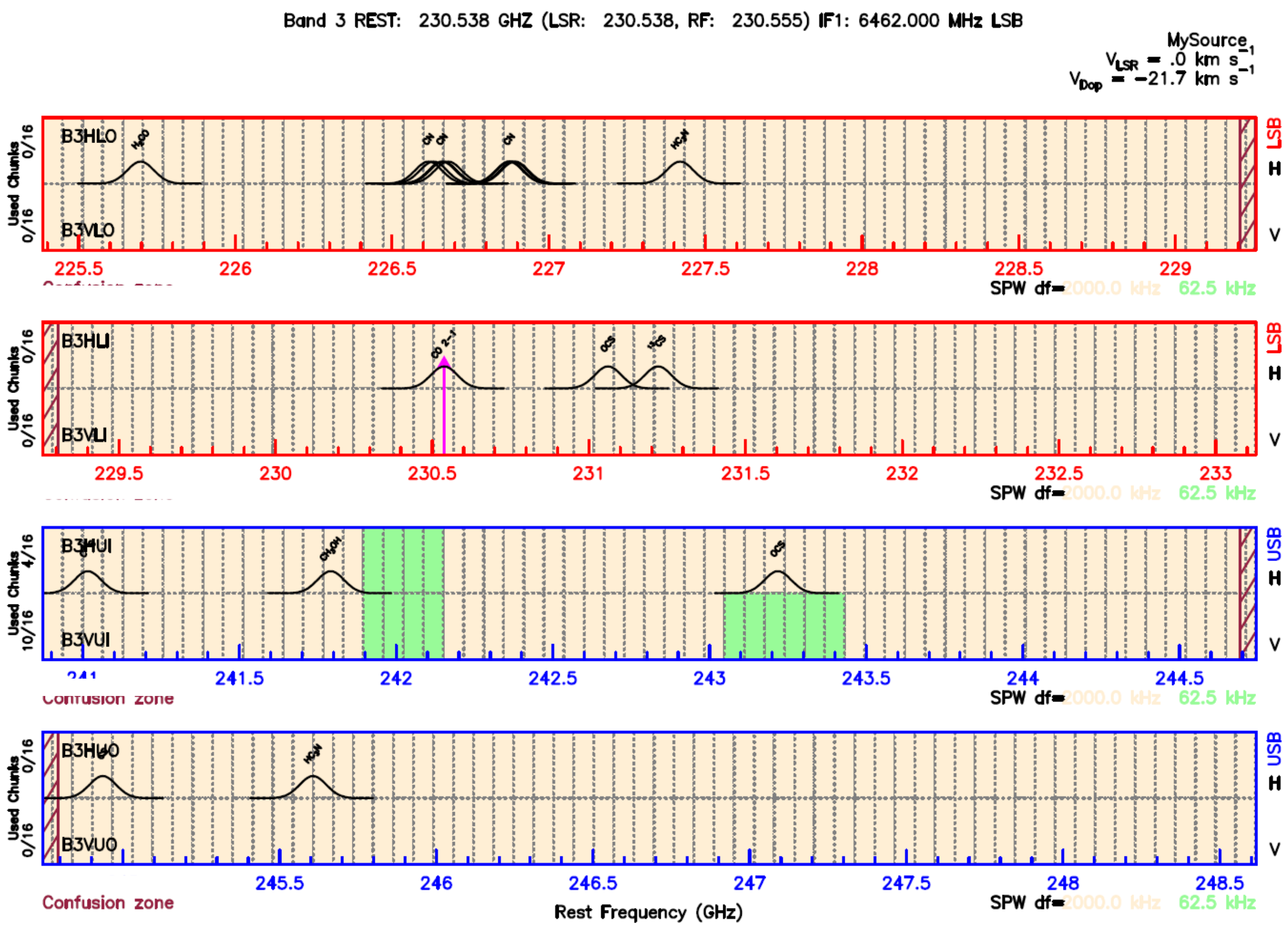
```
PLOT
PLOT /RECEIVER
```



NOEMA setups in ASTRO

Define Spectral Windows

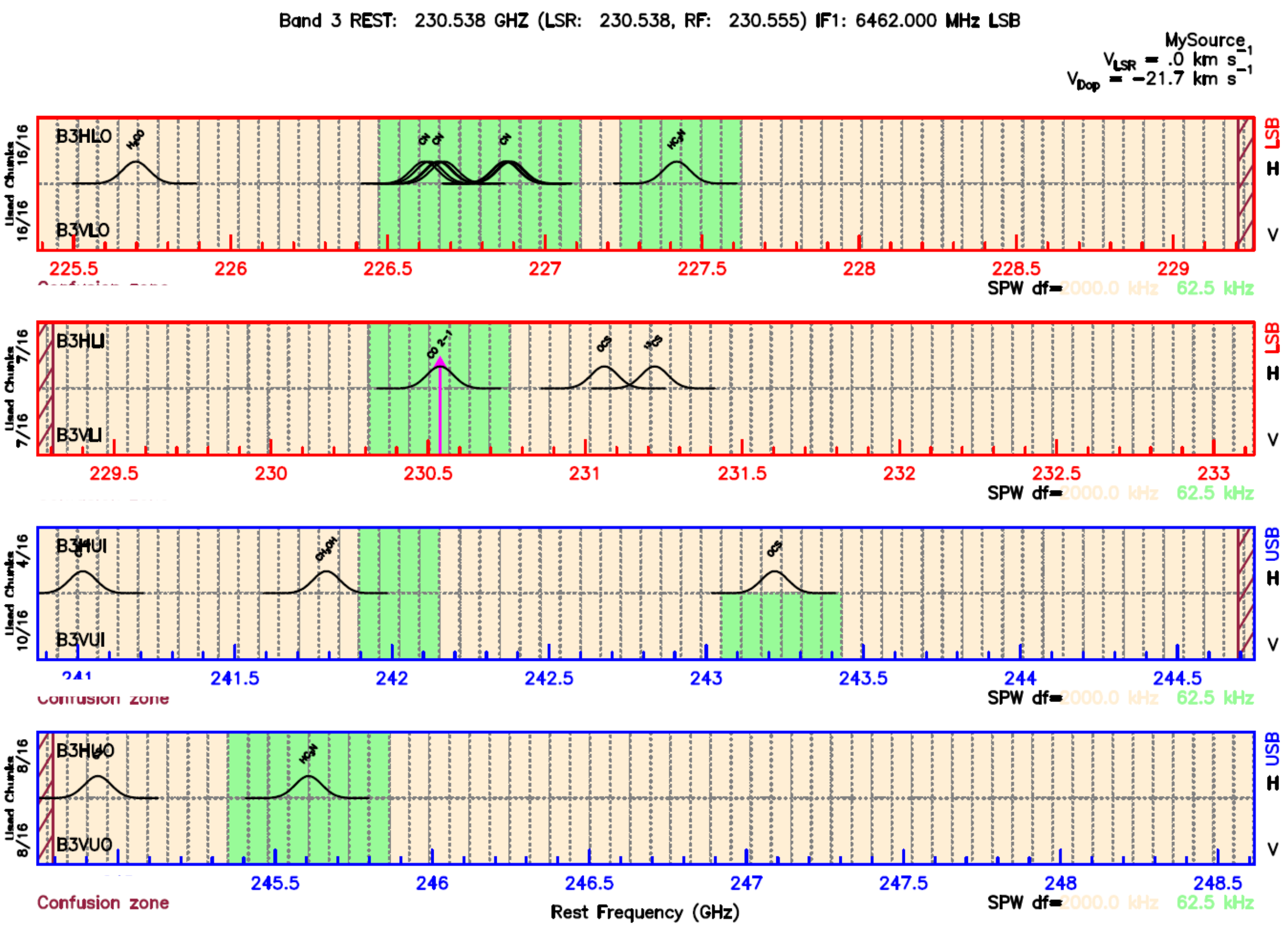
```
BASEBAND ! All basebands selected
```



NOEMA setups in ASTRO

Define Spectral Windows

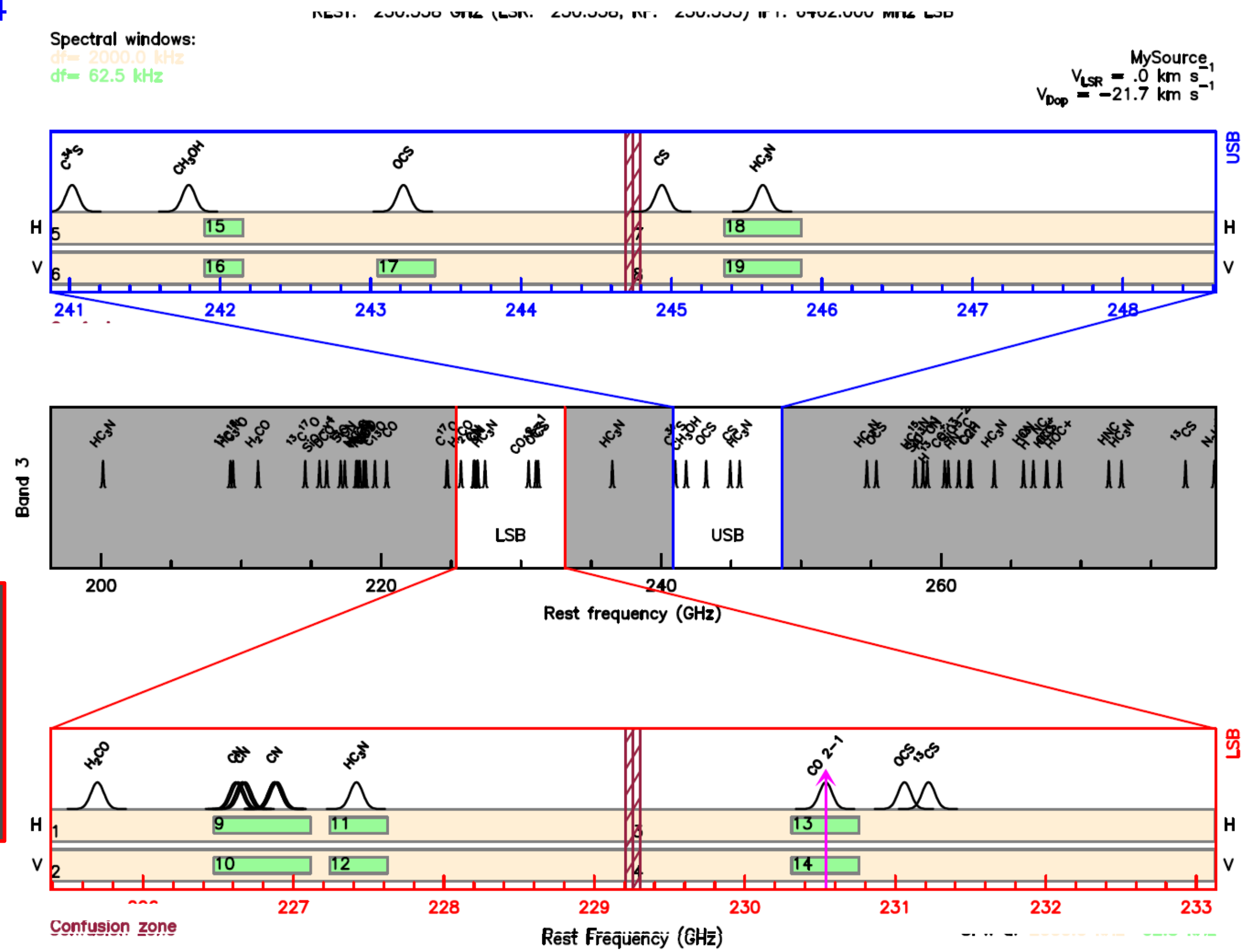
```
BASEBAND ! All basebands selected
SPW /FREQUENCY 230.538 0.4
SPW /RANGE 226.5 227.1
SPW /RANGE 227.3 227.6
SPW /FREQUENCY 245.6 0.4
```



NOEMA setups in ASTRO

Define Spectral Windows

```
BASEBAND ! All basebands selected
SPW /FREQUENCY 230.538 0.4
SPW /RANGE 226.5 227.1
SPW /RANGE 227.3 227.6
SPW /FREQUENCY 245.6 0.4
PLOT /RECEIVER
PROPOSAL /FILE File.ext
! write the minimal series
of commands define to set up
the instrument
(in NOEMAOFFLINE language)
```



The file created by the PROPOSAL command contains all the information required by the Proposal Management System to define a typical hardware setup.

NOEMA spectral setups in ASTRO

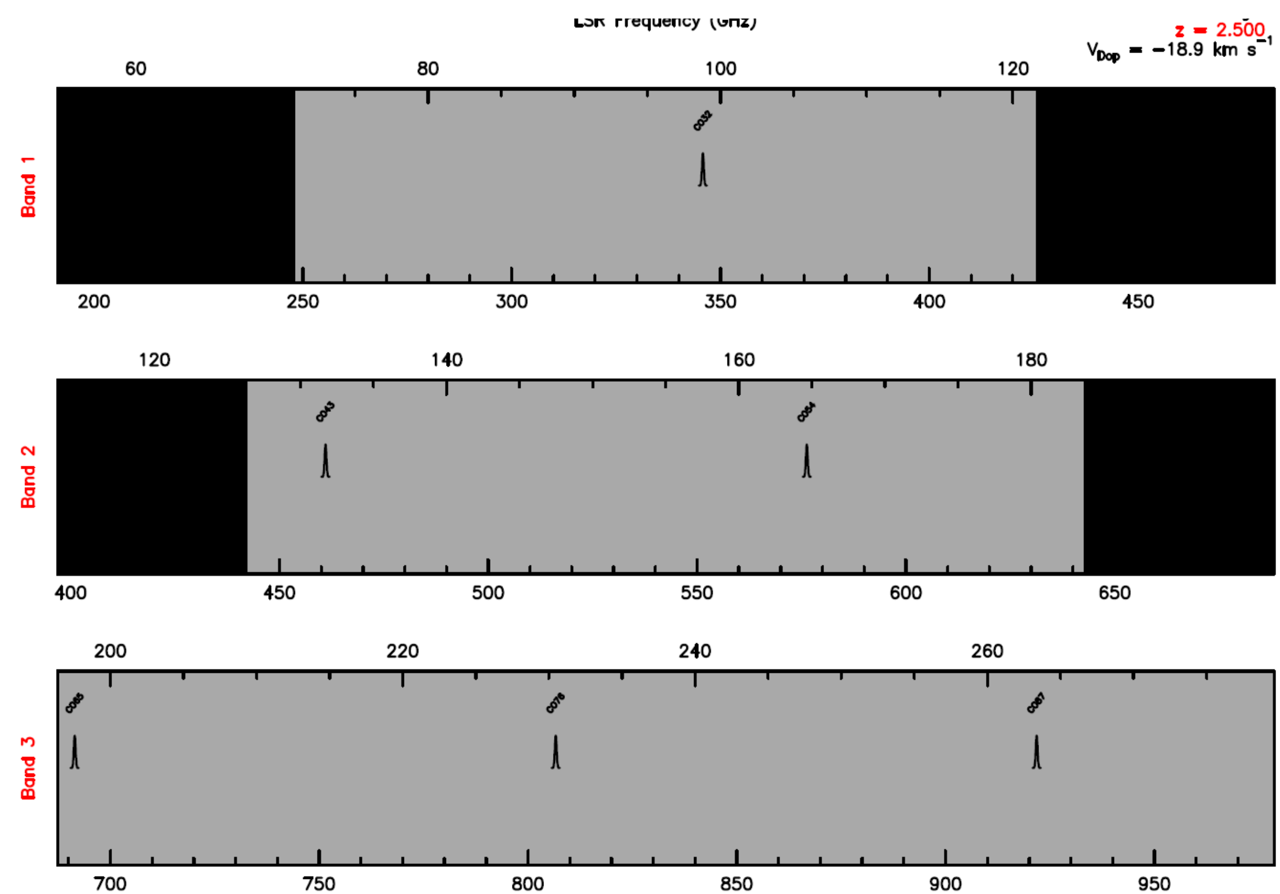
Frequency axes

- All previous ASTRO plots were in REST frequency
- Actual frequency in the receiver is RF
- $F_{RF} = F_{REST}$ x DopplerFactor
  - Observatory contribution:
    - Earth rotation + revolution (<30 km/s ~ 10 MHz @ 100 GHz)
      Varies with time
  - Source contribution:
    - LSR velocity (~100 km/s ~ 30 MHz @ 100 GHz)
    - Redshift
      - 350GHz REST @ z=2.5 observed at ~100 GHz in RF
- Doppler corrections at NOEMA
  - Source LSR taken into account
    - F_{LO} is shifted
  - Earth Doppler corrected on real time (Doppler tracking)
    - F_{LO} changes with time
  - Redshift not corrected
    - Compute redshifted frequency and assume z and LSR = 0
    - ASTRO can help (`SET FREQUENCY [LSR|REST]`)

NOEMA spectral setups in ASTRO

Example with redshifted source

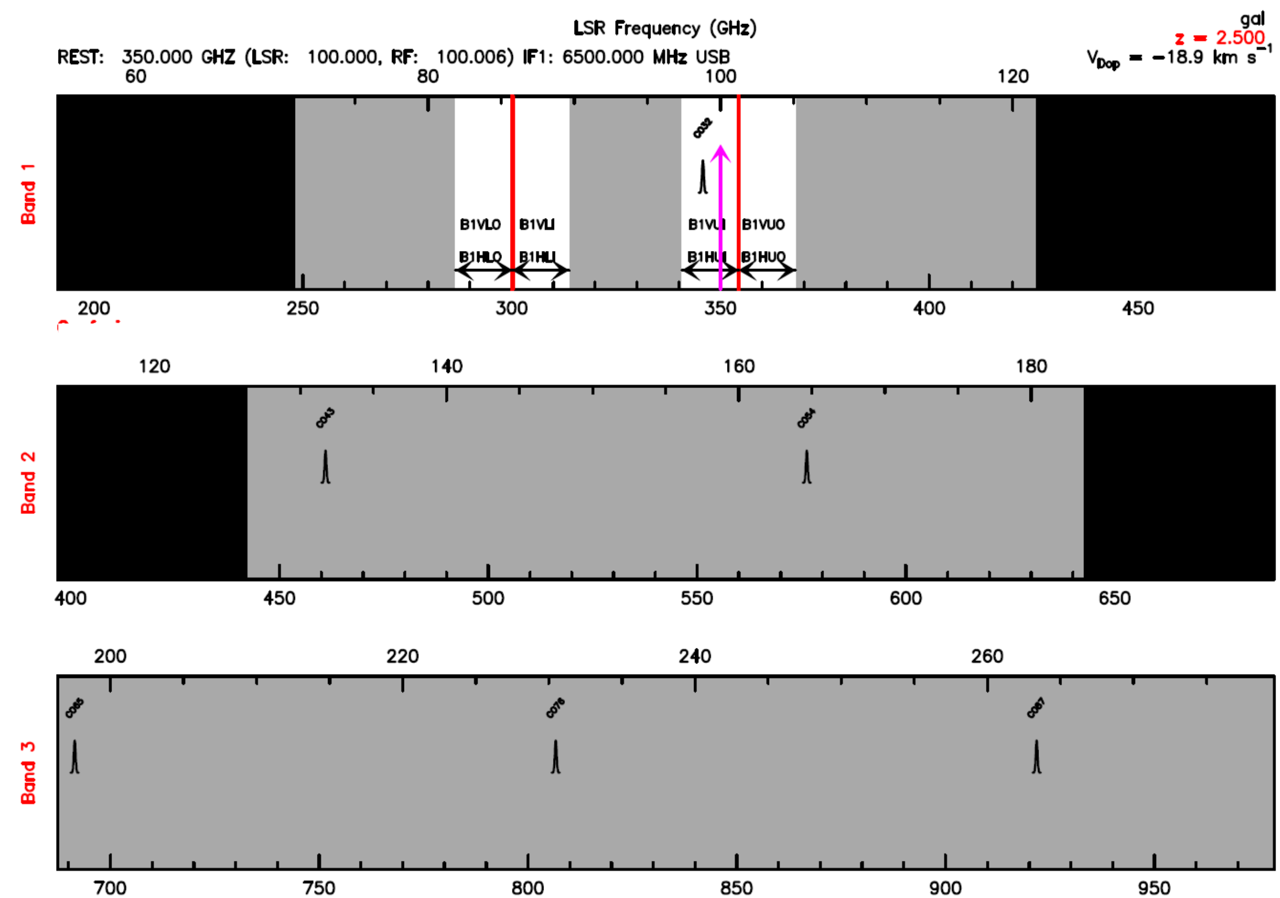
```
SET FREQUENCY REST LSR ! Main axis=REST, Secondary=LSR
! Main axis = Lower axis on plot + Input/Ouput in terminal
CATA CO.DAT /LINE ! Local file with only CO transitions
SET LINES GAUSS 500
SOURCE GAL EQ 2000 10 10 RED 2.5
TUNING
```



NOEMA spectral setups in ASTRO

Example with redshifted source

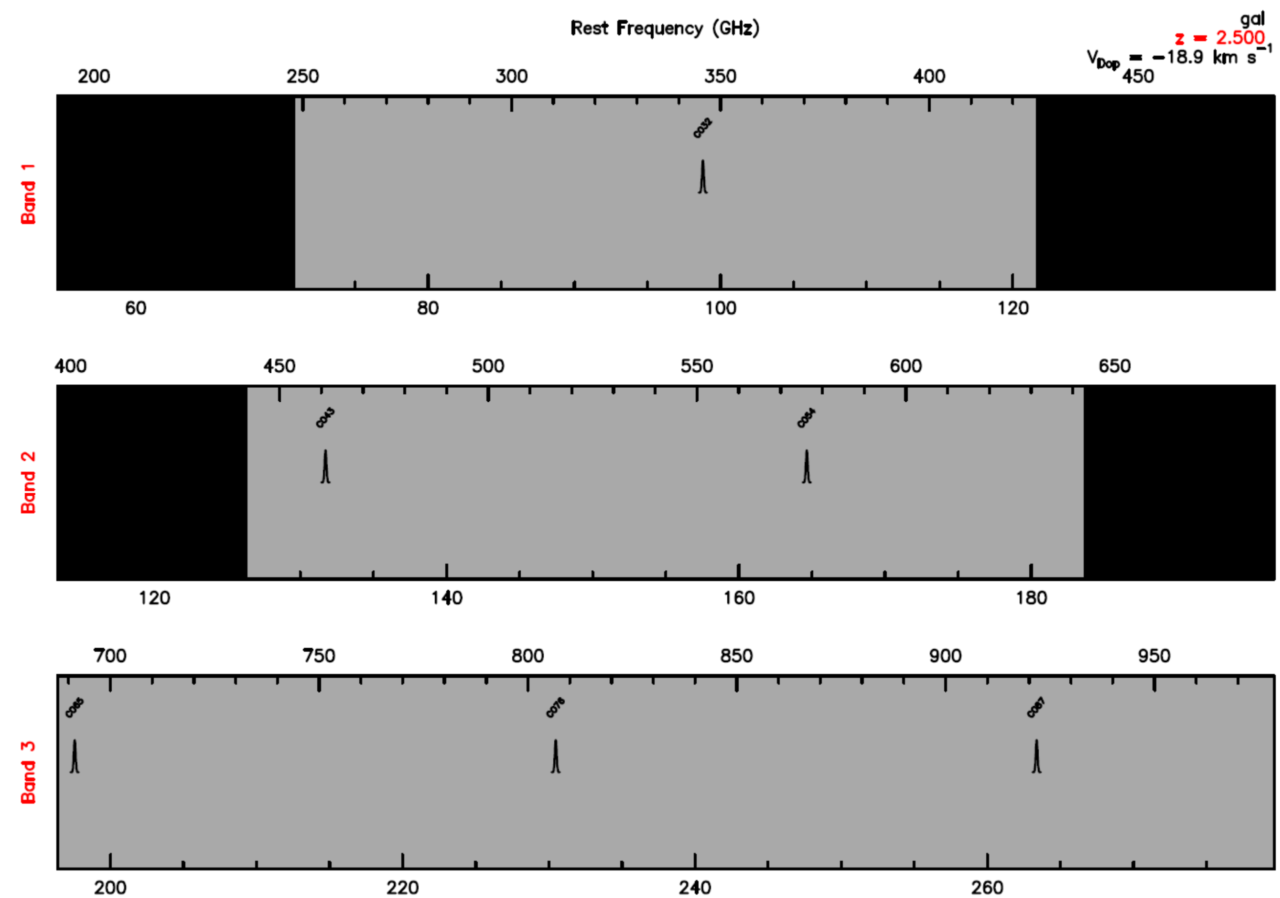
```
SET FREQUENCY REST LSR ! Main axis=REST, Secondary=LSR
! Main axis = Lower axis on plot + Input/Ouput in terminal
CATA CO.DAT /LINE ! Local file with only CO transitions
SET LINES GAUSS 500
SOURCE GAL EQ 2000 10 10 RED 2.5
TUNING
TUNING 350 USB 6500
```



NOEMA spectral setups in ASTRO

Example with redshifted source

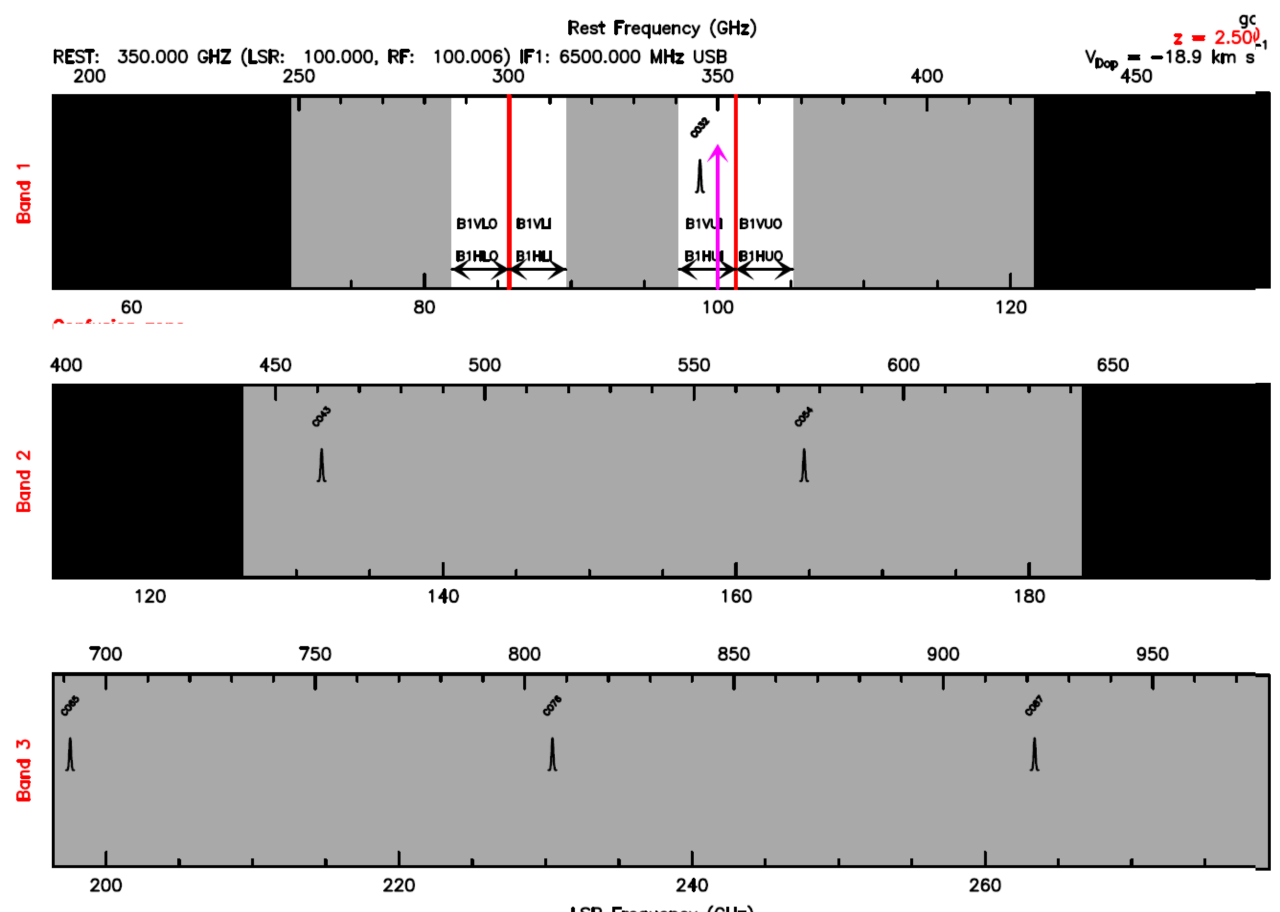
```
SET FREQUENCY REST LSR ! Main axis=REST, Secondary=LSR
! Main axis = Lower axis on plot + Input/Ouput in terminal
CATA CO.DAT /LINE ! Local file with only CO transitions
SET LINES GAUSS 500
SOURCE GAL EQ 2000 10 10 RED 2.5
TUNING
TUNING 350 USB 6500
SET FREQ LSR REST
TUNING
```



NOEMA spectral setups in ASTRO

Example with redshifted source

```
SET FREQUENCY REST LSR ! Main axis=REST, Secondary=LSR
! Main axis = Lower axis on plot + Input/Ouput in terminal
CATA CO.DAT /LINE ! Local file with only CO transitions
SET LINES GAUSS 500
SOURCE GAL EQ 2000 10 10 RED 2.5
TUNING
TUNING 350 USB 6500
SET FREQ LSR REST
TUNING
TUNING 100 USB 6500
```

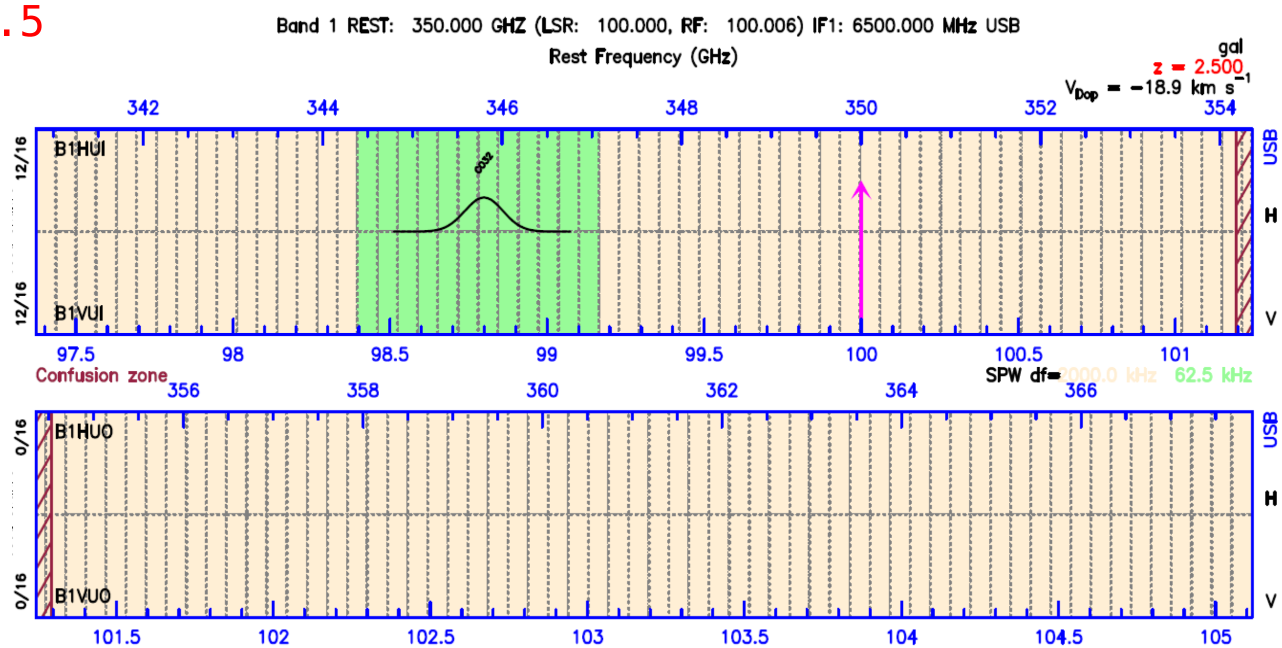


NOEMA spectral setups in ASTRO

Example with redshifted source

```
SET FREQUENCY REST LSR ! Main axis=REST, Secondary=LSR
! Main axis = Lower axis on plot + Input/Ouput in terminal
CATA CO.DAT /LINE ! Local file with only CO transitions
SET LINES GAUSS 500
SOURCE GAL EQ 2000 10 10 RED 2.5
TUNING
TUNING 350 USB 6500
SET FREQ LSR REST
TUNING
TUNING 100 USB 6500
BASEBAND U /MODE 2000 62.5
SPW /FREQUENCY 98.8 0.7
```

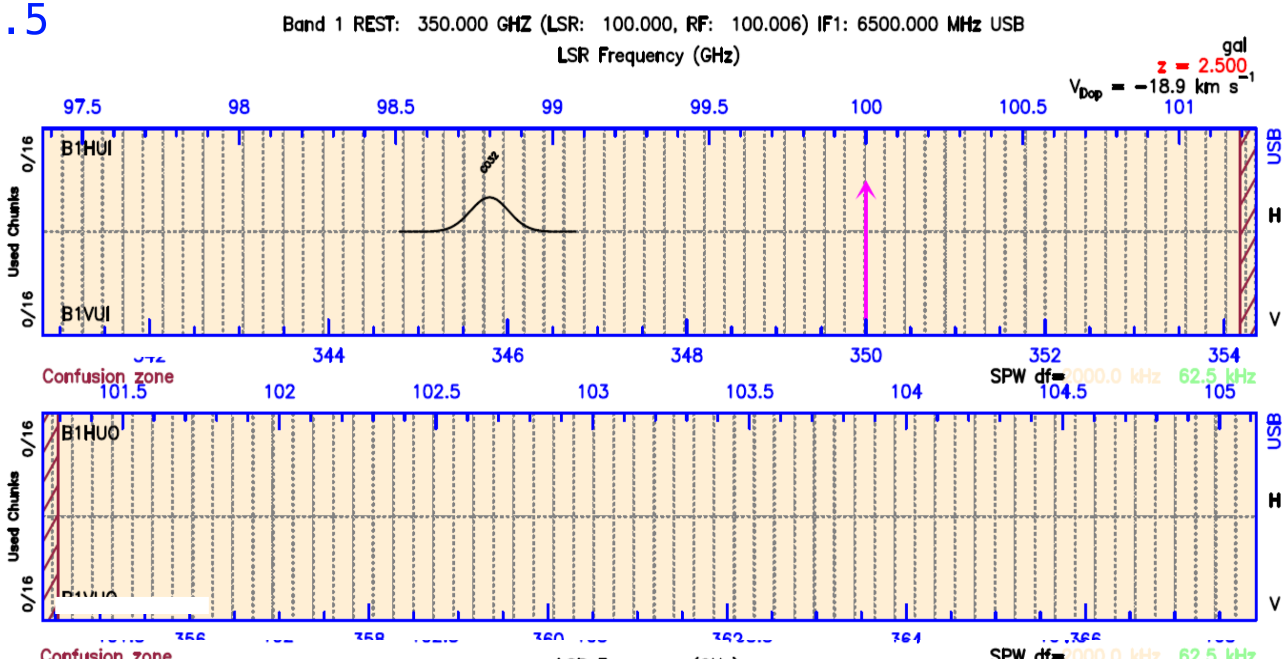
Chunks 34 to 45



NOEMA spectral setups in ASTRO

Example with redshifted source

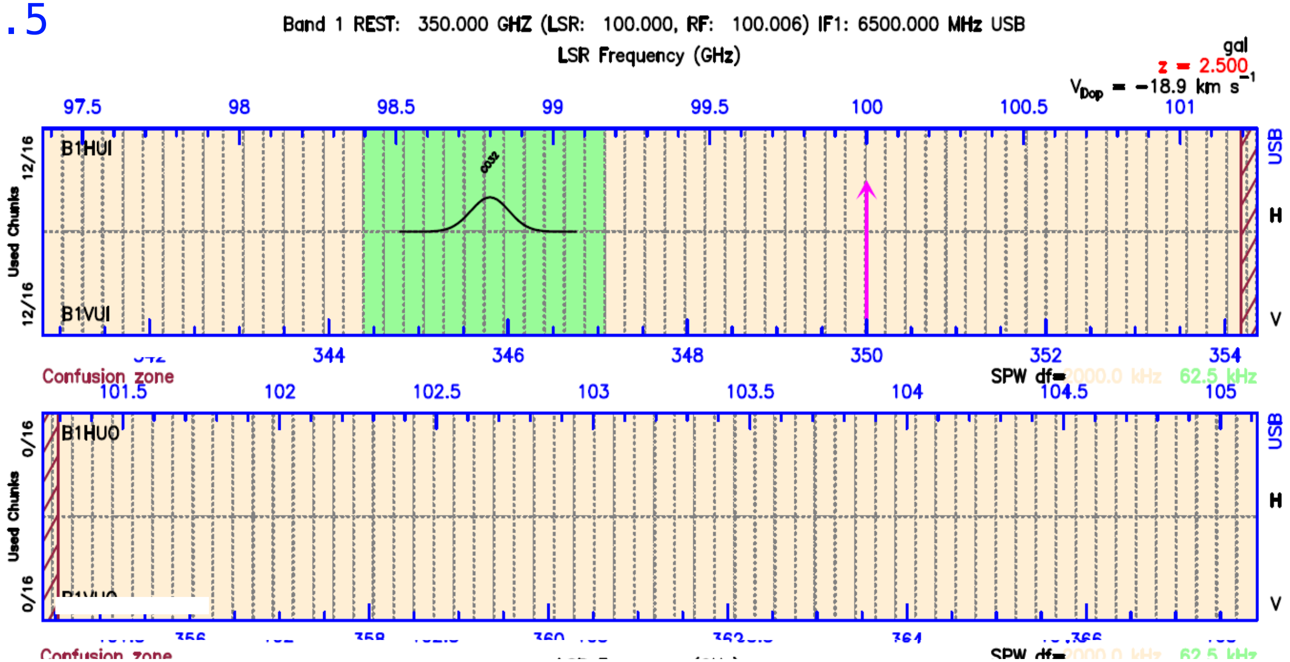
```
SET FREQUENCY REST LSR ! Main axis=REST, Secondary=LSR
! Main axis = Lower axis on plot + Input/Ouput in terminal
CATA CO.DAT /LINE ! Local file with only CO transitions
SET LINES GAUSS 500
SOURCE GAL EQ 2000 10 10 RED 2.5
TUNING
TUNING 350 USB 6500
SET FREQ LSR REST
TUNING
TUNING 100 USB 6500
BASEBAND U /MODE 2000 62.5
SPW /FREQUENCY 98.8 0.7
    Chunks 34 to 45
RESET
SET FREQ REST LSR
BASEBAND U
```



NOEMA spectral setups in ASTRO

Example with redshifted source

```
SET FREQUENCY REST LSR ! Main axis=REST, Secondary=LSR
! Main axis = Lower axis on plot + Input/Ouput in terminal
CATA CO.DAT /LINE ! Local file with only CO transitions
SET LINES GAUSS 500
SOURCE GAL EQ 2000 10 10 RED 2.5
TUNING
TUNING 350 USB 6500
SET FREQ LSR REST
TUNING
TUNING 100 USB 6500
BASEBAND U /MODE 2000 62.5
SPW /FREQUENCY 98.8 0.7
    Chunks 34 to 45
RESET
SET FREQ REST LSR
BASEBAND U
SPW /FREQ 345.8 2.45
! 98.8*3.5=345.8, 0.7*3.5=2.45
    Chunks 34 to 45
```



NOEMA spectral setups in ASTRO

Example with redshifted source

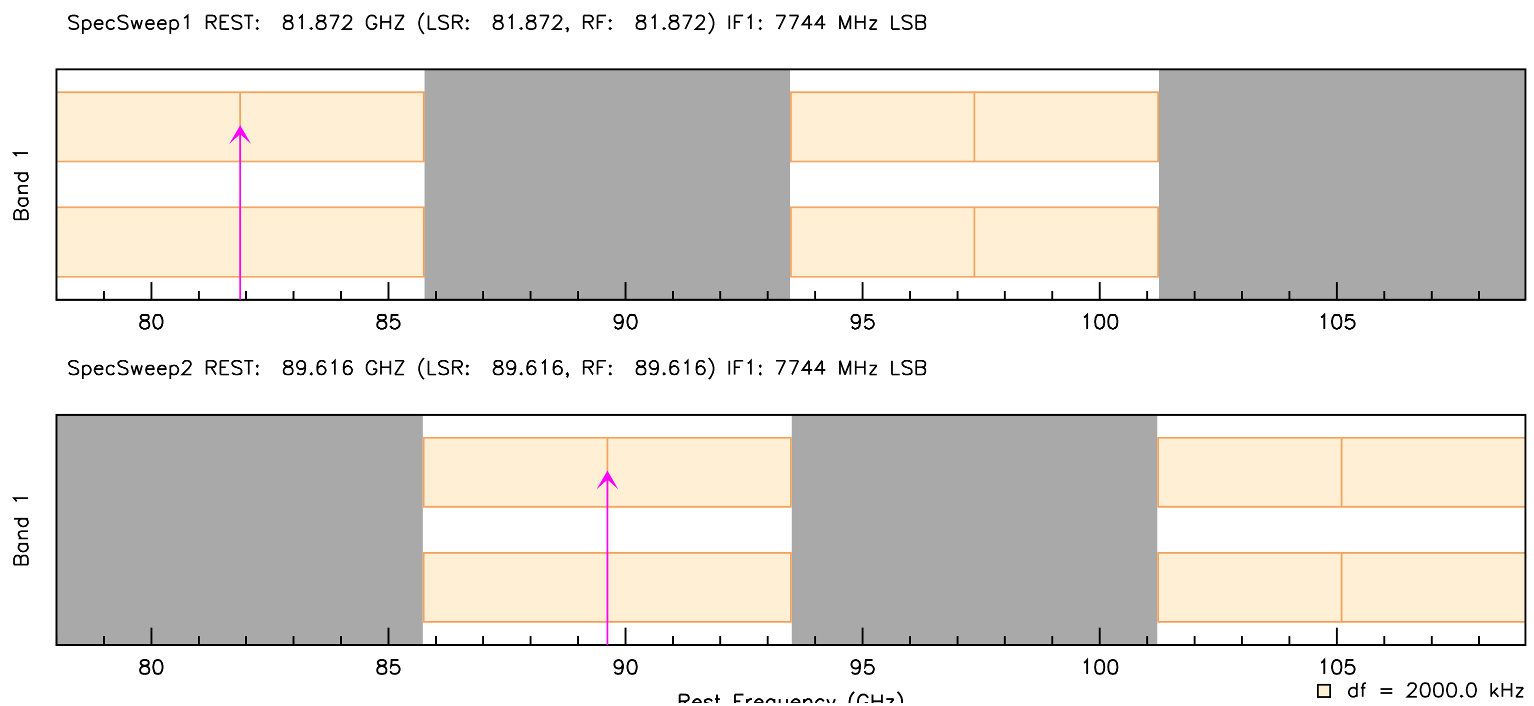
```
SET FREQUENCY REST LSR ! Main axis=REST, Secondary=LSR
! Main axis = Lower axis on plot + Input/Ouput in terminal
CATA CO.DAT /LINE ! Local file with only CO transitions
SET LINES GAUSS 500
SOURCE GAL EQ 2000 10 10 RED 2.5
TUNING
TUNING 350 USB 6500
SET FREQ LSR REST
TUNING
TUNING 100 USB 6500
BASEBAND U /MODE 2000 62.5
SPW /FREQUENCY 98.8 0.7
RESET
SET FREQ REST LSR
BASEBAND U
SPW /FREQ 345.8 2.45
PROPOSAL /file MyFile2.astro
```

```
ASTRO> type MyFile2.astro
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
! BEGIN INCLUDE_SETUP
SET LINES GAUSS 500.000
SOURCE GAL EQ 2000.000 10:00:00.000 10:00:00.000 RED 2.500000
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
SET FREQUENCY REST LSR
TUNING 350.000000 USB 6500.000
BASEBAND B1HLO OFF
BASEBAND B1HLI OFF
BASEBAND B1HUI /MODE  2000.00 62.50
SPW /CHUNK 34 TO 45
BASEBAND B1HUO /MODE  2000.00 62.50
BASEBAND B1VLO OFF
BASEBAND B1VLI OFF
BASEBAND B1VUI /MODE  2000.00 62.50
SPW /CHUNK 34 TO 45
BASEBAND B1VUO /MODE  2000.00 62.50
! END INCLUDE_SETUP
```

Prepare interlaced tunings

1 Command to define several tunings:

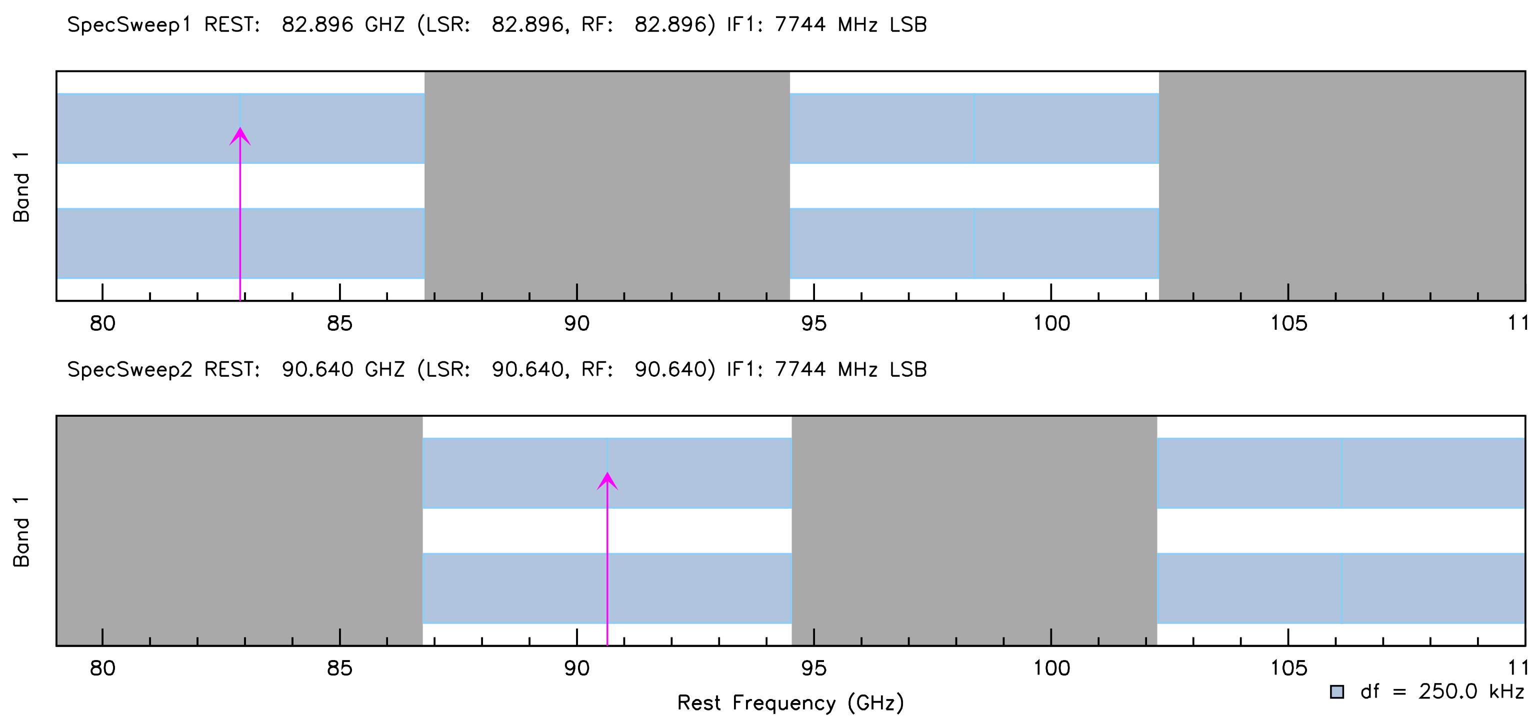
- `SPECSWEEP /NTUNING 2 78 ! 2 tunings, starting at 78GHz, using default correlator mode`



Prepare interlaced tunings

1 Command to define several tunings:

- `SPECSWEEP /NTUNING 2 78 ! 2 tunings, starting at 78GHz, using default correlator mode`
- `SPECSWEEP 250 /NTUNING 2 110 MAX ! 2 tunings, ending at 110GHz, 250kHz channel spacing correlator mode`



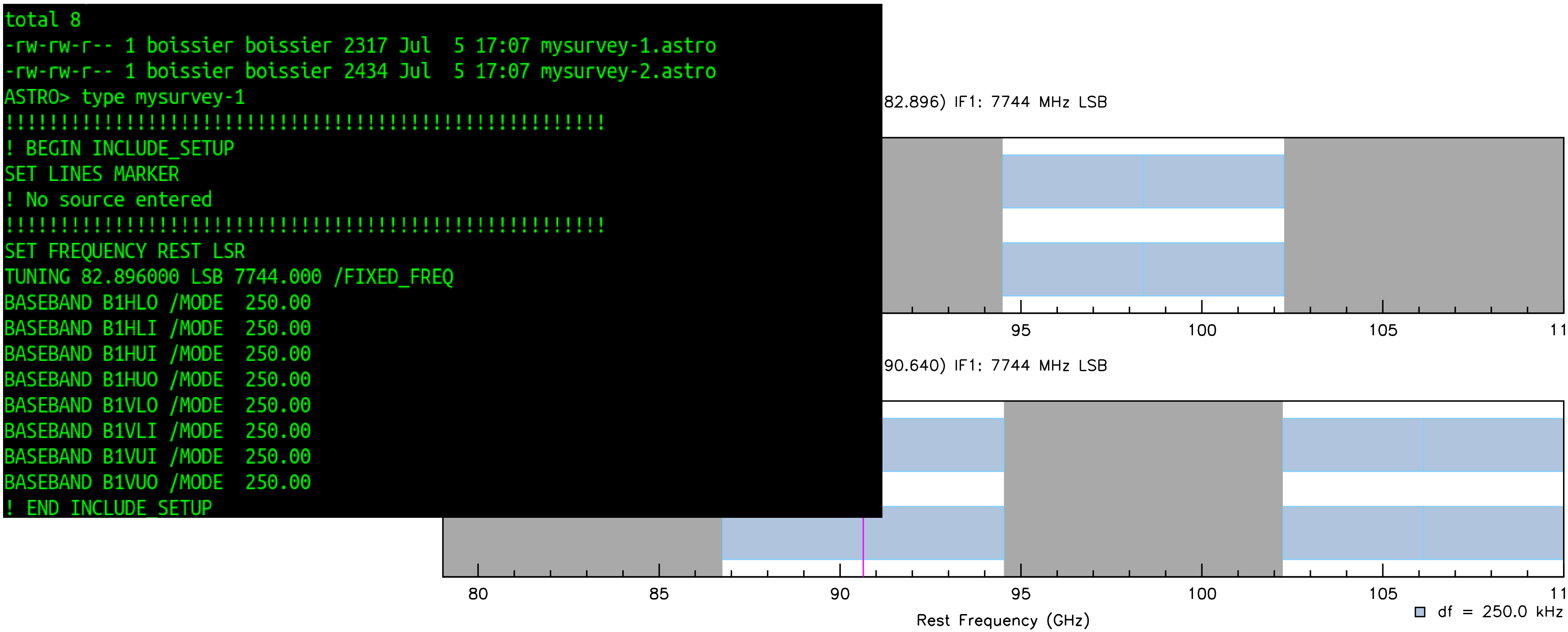
Prepare interlaced tunings

1 Command to define several tunings:

- SPECSWEEP /NTUNING 2 78 ! 2 tunings, starting at 78GHz, using default correlator mode
- SPECSWEEP 250 /NTUNING 2 110 MAX ! 2 tunings, ending at 110GHz, 250kHz channel spacing correlator mode
- SPECSWEEP 250 /NTUNING 2 110 MAX /FILE mysurvey

  ! 2 tunings, ending at 110GHz, 250kHz channel spacing correlator mode

  ! + 2 files created, ready to be uploaded to a technical sheet in PMS



```
total 8
-rw-rw-r-- 1 boissier boissier 2317 Jul  5 17:07 mysurvey-1.astro
-rw-rw-r-- 1 boissier boissier 2434 Jul  5 17:07 mysurvey-2.astro
ASTRO> type mysurvey-1
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
! BEGIN INCLUDE_SETUP
SET LINES MARKER
! No source entered
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
SET FREQUENCY REST LSR
TUNING 82.896000 LSB 7744.000 /FIXED_FREQ
BASEBAND B1HLO /MODE  250.00
BASEBAND B1HLI /MODE  250.00
BASEBAND B1HUI /MODE  250.00
BASEBAND B1HUO /MODE  250.00
BASEBAND B1VLO /MODE  250.00
BASEBAND B1VLI /MODE  250.00
BASEBAND B1VUI /MODE  250.00
BASEBAND B1VUO /MODE  250.00
! END INCLUDE_SETUP
```